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THE EFFECTS OF PACING ON PROGRAMED LEARNING UNDER SEVERAL ADMINISTRATIVE CONDITIONS.
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*PROGRAMED INSTRUCTION, *PACING, *PROGRAMING, PROGRAMING PROBLEMS, SIXTH GRADE, TWELFTH GRADE, *HIGH ACHIEVERS, *LOW ACHIEVERS, FIXED SEQUENCE, SELF PACING MACHINES, PITTSBURGH, PENNSYLVANIA

THE GENERAL PURPOSE OF THIS STUDY WAS TO EVALUATE THE EFFICACY OF PERMITTING SIXTH- AND TWELFTH-GRADE STUDENTS TO ADOPT THEIR OWN WORK RATES DURING PROGRAMED INSTRUCTION. SPECIFIC COMPARISONS WERE MADE BETWEEN LOW- AND HIGH-ABILITY STUDENTS WORKING (1) UNDER SELF-PACED VERSUS FIXED-PACED CONDITIONS AND (2) IN GROUP SETTINGS VERSUS ISOLATED SETTINGS. AT BOTH GRADE LEVELS, THE HIGH-ABILITY STUDENTS PERFORMED SUPERIOR TO LOW-ABILITY STUDENTS. GROUP SETTINGS LED TO SLOWER, SELF-ADOPTED WORK RATES AND LOWER PROGRAM ERROR RATES THAN DID THE ISOLATED SETTINGS. HOWEVER, SETTING HAD NO RELIABLE EFFECT ON POST-TEST OR RETENTION SCORES. THE SELF-ADOPTED WORK RATES WERE HIGHLY STABLE ON TWO PROGRAMS. IT WAS CONCLUDED THAT THE ASSUMPTIONS UNDERLYING THE ADMINISTRATIVE STRATEGY CALL FOR SELF-PACING BECOME BETTER JUSTIFIED AT HIGHER GRADE LEVELS. TWELFTH-GRADERS ADOPTED WORK RATES WHICH CORRESPONDED CLOSELY WITH THEIR ABILITY. SIXTH GRADERS, HOWEVER, ADOPTED WORKRATES WHICH DID NOT CORRESPOND WELL WITH THEIR ABILITY AND WHICH OFTEN WERE EITHER TOO FAST OR TOO SLOW TO PERMIT EFFICIENT LEARNING. REMEDIAL COURSES OF ACTION WERE SUGGESTED. IT WAS RECOMMENDED THAT FUTURE RESEARCH BE DIRECTED TOWARD DETERMINING THE GENERALITY OF UNDERACHIEVEMENT RESULTING FROM MALADAPTIVE SELF-PACING STYLES, AND TOWARD DEVELOPING TECHNIQUES TO REMEDY SUCH STYLES. (JC)

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# THE EFFECTS OF PACING ON PROGRAMMED LEARNING UNDER SEVERAL ADMINISTRATIVE CONDITIONS

Gerard C. Kress Jr., Principal Investigator

May 1966

AMERICAN INSTITUTES FOR RESEARCH

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# FOREWORD

The research reported in this volume was conducted under a grant from the U. S. Department of Health, Education, and Welfare, Office of Education, under Title VII, the National Defense Education Act of 1958, Project No. 1314, Grant No. 7-48-7670-262. Data analyses were partially supported by National Science Foundation grants (No. GP-2091 and No. G-11309) to the University of Pittsburgh Computing Center.

The author is indebted to numerous people for their cooperation and participation in this project. Mr. Clair Cogan and Dr. Merwin Himmler of the Pittsburgh City Schools and Sister M. Rosalie of the Diocesan Schools of Pittsburgh, as well as the staff and students of several schools, gave generously of their time and effort to make the study possible. Anita Czujko, Margaret Samways, and Zita Glasgow assisted in the preparation of programmed materials. Betty Finney coordinated the administrative details of the study. Drs. George Gropper and David Klaus provided advice and guidance both in the execution of the research and the preparation of this report.

# ABSTRACT

This study was concerned with the effects of alternate pacing strategies for administering programmed instruction to various types of students. Specific comparisons were made of both low and high ability students working (1) under self-paced versus fixed-paced conditions, and (2) in group settings versus isolated settings. These comparisons were made both at Grades 6 and 12.

At both grade levels it was found that: (1) The performance of high-ability students was superior to that of low-ability students; (2) The group setting led to slower, self-adopted work rates and lower program error rates than did the isolated setting. However, setting had no reliable effect on either immediate posttest or retention test scores; (3) Self-adopted work rates were highly stable ($r = .72$ to $.78$) on two programs.

At Grade 6, it was found that: (1) Self-adopted work rate (measured by completion time) was only modestly correlated with IQ ($r = -.14$); (2) Many students displayed non-adaptive work rate and achievement patterns, either fast work rates which were accompanied by low achievement or slow work rates which were accompanied by high achievement; (3) Slow fixed pacing did <u>not</u> result in more effective learning for low-IQ students; (4) Fast fixed pacing <u>did</u> result in more efficient learning without achievement decrement for high-IQ students.

At Grade 12, it was found that: (1) Self-adopted work rate was highly correlated with IQ ($r = -.61$); (2) Fewer students than at Grade 6 displayed non-adaptive work rate and achievement patterns; (3) Slow fixed pacing did not result in more effective learning for low-IQ students; (4) Fast fixed pacing led to achievement decrement among high-IQ students.

It was concluded that the assumptions underlying the administrative strategy calling for self pacing become better justified at higher grade levels. Twelfth graders adopt work rates which correspond closely with their ability and which tend to optimize learning effectiveness and efficiency. Sixth graders, on the other hand, adopt work rates which do not correspond well with their ability level and which, in many instances, are either too fast to permit effective learning or too slow to permit efficient learning.

The strategy of forcing high-ability students to work faster (hence more efficiently) appears to have remedial value for sixth graders. However, the strategy of providing a slow, fixed pace is not adequate to remedy fast-work rate, low-achievement patterns at either grade. Thus, externally controlled pacing is an effective technique for heightening efficiency among deliberate workers, at least at the lower grade levels, but not for fostering more deliberate work habits among careless workers.

It was suggested that future research be directed toward determining the generality of under-achievement resulting from maladaptive self-pacing styles and toward developing more effective techniques to remedy such styles.



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# INTRODUCTION

A widely held view among programmers which has survived a number of years of research in the field, is that students should be permitted to adopt their own pace when working through a program. Thus, if programs are administered under student-paced or "self-paced" conditions, it is generally felt that learning will be optimally effective and efficient.

One assumption underlying this view is that in order to be able to respond correctly to each frame of instruction each student possesses a unique time requirement. The amount of time required is thought to be an inverse function of his ability. The less able student will require more time to respond correctly than the more able student.

A second assumption underlying the notion that self-paced program administration leads to optimal learning is that differences in self-adopted rates of work during the program will coincide with differences in ability. Students will spend about as much time as they require to respond correctly to each frame. The more able students will adopt relatively fast work rates and complete the program in less time, while the less able students will adopt relatively slow work rates and require more time to complete the program. In this manner, all students will learn as effectively and efficiently as the program and their abilities permit.

In several investigations, self-paced and fixed-paced administrative strategies were systematically compared (Silverman & Alter, 1961; Alter & Silverman, 1962; Feldhusen & Birt, 1962; Frye, 1963; Carpenter & Greenhill, 1963). During fixed-paced instruction, individuals were not permitted to adopt their own work rates, but were forced to work at a rate (or pace) which was externally imposed. No differences in achievement were observed between self-paced and fixed-paced instruction. These studies indicate that self-pacing may not be a necessary condition for effective programmed learning. On the other hand, they contain little evidence to challenge the notion that self-pacing, wherever possible, represents the optimal condition.

Such a challenge was issued by Carpenter who, in a recent article (1964), asserts that: "The rate at which students study and learn normally and habitually are very probably not the best or optimum rates for the most effective learning." The implication of Carpenter's assertion is that programmed learning may actually be enhanced by exerting appropriate external control over a student's working pace.

In a recently completed series of experiments, Kress and Gropper (1964a, 1964b) report evidence which tends to support the position that external control over the working pace may be superior to self-control. In one experiment (Kress & Gropper, 1964b), a group of eighth-graders working under self-paced conditions was found to be inferior to a matched group working on the same program under externally-paced conditions. The self-paced group committed more errors during the program and achieved significantly lower scores on both post-test and retention test. As it turned out, the average working pace adopted by this group was also faster than that externally selected for the fixed-paced group. Thus, superiority of the latter group was attributed to the fact that they were forced to spend more time to complete the program. It was reasoned that this provided better opportunity for the construction and rehearsal of correct responses.

These findings supported those from another experiment (Kress & Gropper, 1964a) involving the administration of two self-paced programs to several hundred eighth-graders. It was found that a substantial number of students consistently adopted either a relatively rapid pace which was accompanied by high error rates and low achievement, or a relatively slow pace which was accompanied by very few errors and virtually perfect achievement. The former group adopted a pace which seemed clearly too fast to permit optimal achievement. The latter adopted a pace which <u>may</u> have been slower than was necessary, considering other students who achieved equally high scores in less time.

The position assumed by Carpenter and the observations of Kress and Gropper question the adequacy of an administrative strategy that permits students to adopt their own working pace during a program. They do not question the assumption that students require different amounts of time to learn effectively. However, they both appear to question the assumption that differences in self-adopted work rates coincide with differences in ability. Many of the students observed by Kress and Gropper adopted work rates which were non-adaptive. Their work rates were neither ability-related nor consistent with optimally effective and efficient learning.

A number of studies have been conducted which bear on the congruence of student-adopted work rates and their time requirements. It will be helpful to consider the relevant research on this point to note the discrepancies which exist and to consider a possible explanation for the discrepant findings.

Self-Adopted Work Rate and Ability

Several studies report an inverse relationship between time taken to complete a program and student ability. Cook (1963), in describing the results obtained when 13 students were given an 800-frame chemistry program, reports a rather orderly (coefficient of correlation not reported) negative relationship between time to complete the program and IQ. Each of these students achieved a high criterion score by working at rates inversely related to their intelligence. Carroll (1963) reports a correlation coefficient of -.77 between score on the Carroll-Sapon Modern Language Aptitude Test and time to complete a program on Mandarin Chinese. A 1961 study by Silberman, Melaragno, Coulsen, and Estavan revealed a correlation coefficient of -.52 between time to complete a program and score on the Henmon-Nelson Test of Mental Ability.

In the Krass and Gropper (1964a) study, the relationship between work rate and IQ was not nearly as orderly as that reported in previous studies. Based upon 267 and 353 subjects in two different experiments, they obtained correlation coefficients of -.44 and -.34, respectively. Thus, although the rate at which students worked on the program in this study was IQ-related, the relationship was not as strong as might be expected on the basis of the experiments described above. In addition, work rate, on the basis of data from two separate programs, was found to be a remarkably stable individual characteristic. Time scores on the two programs used in each study correlated .80 and .83 and these coefficients were reduced very little by partialing-out IQ. It was further observed that many low-ability subjects were consistently fast workers even though they committed large numbers of errors and achieved poor criterion-test scores. Moreover, these data fail to verify the assumption that self-adopted work rate is ability-determined and related to the individual's time requirement for successful responding. Indeed, the work rates of these subjects seemed to be a rather stylistic habit that was largely unaffected by experienced success or failure in responding to the frames.

## Self-Paced and Fixed-Paced Administrative Strategies

In a number of studies in which self versus external control over the working pace was specifically considered (Folletie, 1961; Silverman & Alter, 1961; Alter & Silverman, 1962; Feldhusen & Birt, 1962; Carpenter & Greenhill, 1963) only one revealed differences in learning between self-pacing and fixed-pacing strategies: Folletie found self-pacing to be superior in terms of learning efficiency.

Folletie interpreted his findings to be evidence that students should be permitted to work at self-adopted rates. The others interpreted their findings as evidence that external control over the working pace need not impair learning. In contrast, Kress and Gropper (1964b) demonstrated that such external control may actually enhance learning.

## Self-Pacing and Grade Level: A Possible Resolution

Rather different judgments regarding the efficacy of the self-pacing strategy arise from the Kress and Gropper (1964a, 1964b) findings as compared to the earlier studies. Kress and Gropper found self-adopted work rate to be relatively independent of ability. They also found self-pacing to be inferior to fixed-pacing. Both findings fail to agree with the bulk of the earlier studies cited. It seemed reasonable to suspect that the differences in outcomes may be explained by the differences in the samples observed.

The observations of high correlations between work rate and ability variables (Cook, 1963; Carroll, 1963; & Silberman, et. al., 1961) were all based on tenth-grade or older students. The comparisons between self-paced and fixed-paced program administration (Folletie, 1961; Silverman & Alter, 1961; Alter & Silverman, 1962; Feldhusen & Birt, 1962; Carpenter & Greenhill, 1963) were all based on college students or military trainees. In contrast, the Kress and Gropper findings were based on the performance of eighth graders.

The discrepancy between the earlier findings and the Kress and Gropper findings, coupled with the fact that they are based upon very different age levels, suggests that the success of self-pacing may be related to the grade level of learners. It is well known that the progression of students through grade school, into high school, and finally into college is accompanied by various screening processes whereby attrition occurs mostly among the less able students. The most notable attrition in the ranks of the low-ability students occurs between high school and college. College students are thus generally more able learners than are grade-school students. Superimposed upon that screening process is the fact that as the students ascend the educational ladder they become increasingly skilled in work and study habits. Both processes would seem to contribute to the apparently greater efficacy of the self-pacing strategy among older students as compared to younger students.

## The Administrative Setting

The particular environments in which programmed instruction has been administered in studies concerned with pacing mode have varied between individual and group settings. Carpenter and Greenhill, Frye, and Kress and Gropper ran externally-paced subjects in groups which worked togehter in a single room. The externally-paced groups employed by other investigators were run individually, on separate teaching machines (Alter & Silverman, 1962; Silverman & Alter, 1961). As for their self-paced condition, Alter and Silverman, Silverman and Alter, and Frye ran their subjects individually. Carpenter and Greenhill, and Kress and Gropper, on the other hand, ran these subjects in groups which met in one room with separate machines or booklets. It is obvious that little uniformity exists among the several studies in this respect. This lack of uniformity may indicate that the investigators did not regard the setting as a particularly relevant feature of the experiment.

However, Frye indicated that his results may well have been due in part to the recognition of subjects of the competitive aspects of the group situation. It was also observed during the Kress and Gropper studies that many subjects attended to the progress of their fellows and may have adjusted their own behavior on this basis. Specifically, it appeared that slow workers tended to hasten their rate in response to the visable progress of their faster-working classmates. It seemed appropriate, therefore, to attend systematically to this aspect of the learning environment so as to clarify the role of administrative setting as well as grade level in the success that students have in adopting an appropriate working pace.

## Purpose

The general purpose of the present study was to evaluate the efficacy of permitting students to adopt their own work rates during programmed instruction. Comparisons were made of both high and low ability students working: (1) under self-paced versus fixed-paced conditions and (2) in group settings versus isolated settings. These comparisons were made both at grades 6 and 12.

By observing both sixth and twelfth graders, it was possible to evaluate the extent to which students at different academic levels differ in their relative ability to adopt work rates which accurately reflect their abilities and which, therefore, optimize their learning from programs. It was expected that particular types of students can be identified who are habitually poor pace-selectors and whose learning can be improved by controlling their pace externally. Further, it was expected that particular types of students can be identified who are habitually poor pace-selectors and whose learning can be improved by controlling their pace externally. Further, it was expected that the extent to which learning can be improved by external pace control would differ between the two grade levels and within each grade depending upon whether group or individual administrative settings were used.

The selection of an "optimal" fixed-pace, designed to maximize learning effectiveness and efficiency, may be clarified by inspection of Fig. 1. Figure 1 is a hypothetical scatter diagram of completion times versus achievement scores for students of a given ability level. The idealized curve represents the parameter of achievement as a function of time. It specifies a negatively accelerating relationship: achievement increases as more time is spent on the program but that, beyond a certain point, the expenditure of additional time results in little gain in achievement. This point, labelled as the "Optimal Pace," corresponds to the smallest possible expenditure of time (the fastest self-adopted work rate) necessary to achieve a high score on the criterion test. The expenditure of less time (a faster work rate) results in less than optimal achievement, whereas expenditure of more time (slower work rates) results in less efficient learning and little gain in achievement.

The area designated as D encompasses the fast-working, low achievers whose achievement is most likely to be raised by forcing a slower pace. Area C represents the slow-working, high achievers whose achievement scores are most likely to remain high even when forced to work at a faster pace. Areas A and F, fast/high and slow/low, represent Ss who are least likely to be improved by changing their habitual self-adopted pace. The relative proportion of Ss whose habitual self-paced performance places them in Areas C or D would determine the extent to which overall improvement is possible for a given program administered to a specific group of students by the imposition of an "optimal" fixed pace.

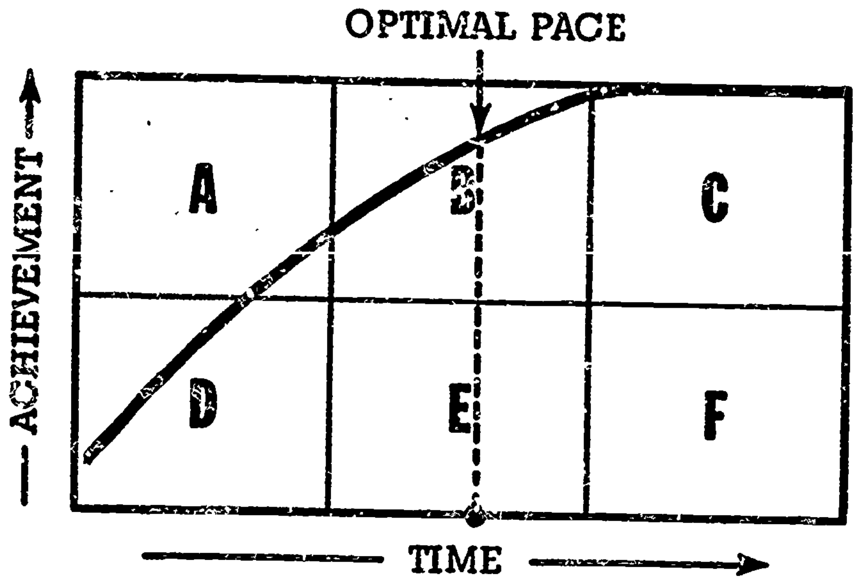


Fig. 1. The idealized parameter of time vs. achievement at a given level of ability.

Based upon the observations of Kress and Gropper (1964a), it was expected that external control of pacing might lead to improved performance over self-pacing as follows: (a) habitually fast-working, low achievers would achieve higher criterion test scores when forced to work at a slower pace, and (b) habitually slow-working, high achievers would be able to work at a faster pace without decrement in criterion scores. The first would result in more effective learning, the second in more efficient learning.

# GRADE 6 EXPERIMENT

In order to assess performance differences between students of different grade levels, all experimental comparisons were made with a sample of sixth graders, then repeated with a sample of twelfth graders. The first experiment of this study was conducted at Grade 6.

## METHOD

### Subjects

The sample of Ss who participated in this experiment consisted of 308 sixth graders. The sample was drawn from four Pittsburgh city schools, two public and two parochial.

### Materials

Lesson materials developed for use in the sixth-grade experiment consisted of: (a) two short preliminary programs which were administered to all Ss in their schools prior to their exposure to one of the experimental treatments; and (b) a longer program which was administered under several different conditions at an experimental site.

Preliminary programs - A 116-frame program on the concepts of "force and motion" and a 90-frame program on "atomic structure of matter" were administered to all sixth-grade Ss in their classrooms. Their purpose was to familiarize Ss with programmed instructional materials and to provide a measure of each S's characteristic work rate, error rate, and achievement level from self-paced programs. These performance measures were subsequently employed, in combination with ability measures, as predictors of performance during and from the experimental program. Both preliminary programs were reproduced in booklets with one frame per page. They might be characterized as linear, requiring constructed responses, and making heavy use of the "vanishing" technique whereby cue support is gradually reduced and responses become longer and more complex. Sample frames from both programs are reproduced, along with the achievement tests used, in Appendix A.

All preliminary tests and programs were administered to Ss in their respective classrooms during three separate sessions which were conducted within a two-week period. The preliminary programs were administered in the classroom-group setting under self-paced conditions. Each S was given a booklet and instructed to work at a pace which would permit him to respond accurately to each frame and to achieve a high score on the criterion test that was to be administered immediately upon completion of the lesson. The general order and spacing of the preliminary sessions is indicated in Table 1.

Experimental program - The program used during the sixth-grade experimental sessions was a 219-frame lesson on some basic concepts of electricity. It dealt with current as a flow of electrons, the attraction and repulsion of particles, batteries, voltage, resistance, current, circuit diagrams, series and parallel circuits and, finally, some applications of Ohm's Law to calculate current in simple examples of each kind of circuit. Sample frames and the criterion test are presented in Appendix A. This program, like the preliminary programs, was linear, required constructed responses and was frequently augmented by line drawings and other visual prompts.

Table 1

Schedule of Preliminary Sessions
Grade 6 Experiment

| Day | Tasks | Approximate Length of Session |
|---|---|---|
| 1 | Pretests on the Atomic Structure, Force & Motion, and Electrical Circuits Programs and the Tinker Speed of Reading Test[1] | 1-1/2 hrs. |
| | 1 - 7 day delay | |
| 2 | Force and Motion Program and Posttest | 2 hrs. |
| | 2 - 7 day delay | |
| 3 | Atomic Structure of Matter Program and Posttest | 2 hrs. |

[1]Published by the University of Minnesota Press, Minneapolis.

All programs underwent several stages of revision on the basis of tryouts with sixth-grade students from a school which was not used in the experimental treatments.

Experimental Design

Those Ss who participated in the preliminary sessions were brought to an experimental site on one of five successive Saturdays and assigned to one of the experimental treatments described below.

Independent variables - This experiment was designed to assess the effects on the programmed learning of both low and high ability students of: (1) Pacing Mode, self and fixed, and (2) Administrative Setting, group and isolated. High and low ability categories were determined by ranking Ss on the basis of IQ scores. Subjects within each category were then randomly assigned to one of four treatment conditions. This resulted in a 2 x 2 x 2 factorial design, or treatments x levels design (Lindquist, 1953), as displayed in Fig. 2. An analysis of variance of IQ scores revealed a highly significant difference between levels ($F < .01$); high IQ mean = 118, low IQ mean = 99. (See Tables 1 and 2, Appendix B.)

Self-paced conditions were based upon much the same procedure as described earlier for the administration of preliminary programs. Under fixed-paced conditions, on the other hand, Ss were required to work on each frame for periods which were externally controlled. Under isolated conditions, Ss worked apart from their fellow students. Under group conditions, Ss worked in classroom-like settings, in the presence of a number of other Ss.

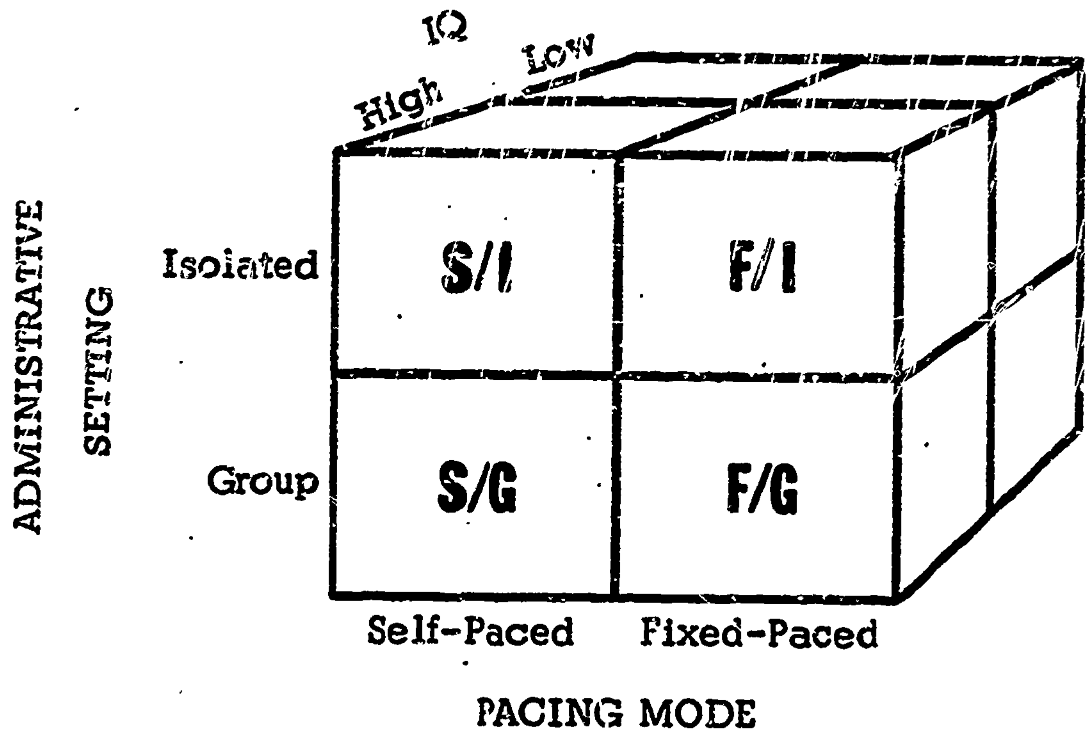


Fig. 2. 2 x 2 x 2 treatments by levels design.
Symbols in each cell refer to the four treatment conditions.

Dependent variables - The dependent variables measured in the experiment were: errors committed during the program, score on an achievement test given immediately after the lesson, and score on the same test given after a delay of 30-33 days. For Ss who were run under self-paced conditions, time to complete the lesson was also recorded as a dependent measure.

The sixth-grade experimental lesson was administered, at a central site, during five consecutive Saturdays, beginning on the first Saturday following the preliminary sessions. Isolated Ss were run at the offices of A·I·R, grouped Ss in a large classroom of a nearby school not attended by any of the Ss. The four treatment conditions under which the lesson was administered are listed below, followed by symbols which will subsequently be used to refer to each condition.

Self-paced, Isolated setting - ($S/I_{High}$, $S/I_{Low}$)

Self-paced, Group setting - ($S/G_{High}$, $S/G_{Low}$)

Fixed-paced, Isolated setting - ($F/I_{High}$, $F/I_{Low}$)

Fixed-paced, Group setting - ($F/G_{High}$, $F/G_{Low}$)

Each of the four conditions is identified in Fig. 2 by its symbol. Reference to the various treatment groups is made by means of these symbols in the section to follow, which describes the procedure employed during the five Saturday sessions.

## Procedure

All self-paced conditions were run during the first two Saturdays. In the $S/I_{Low}$ and $S/I_{High}$ conditions, S was taken by an E to a small room. The instructions were to work through the lesson at a pace which would permit S to learn the material and to do well on the test to be given after the lesson. Each S was informed that since it was desired to know how long people spend on these frames, a record would be kept of his times as he worked along. He was requested not to modify his work rate because of the timing, but rather to work at his usual pace taking as much time as he needed. As S worked, E, using a stopwatch and data form, recorded the number of seconds spent on each frame. A record was also kept of the total time to complete the program. Two rest periods were given, after frames 76 and 151. A posttest was administered immediately after S finished the program.

The $S/G_{Low}$ and $S/G_{High}$ conditions were also conducted during the first two Saturdays. These Ss were run in a large classroom at another building in groups of 20-35, of both high and low IQ. Their instructions were much the same as were given during the preliminary sessions. In this condition, a record was kept only of each S's total time to complete the program. These groups were also given two rest periods and a posttest as they completed the lesson.

Selection of optimal fixed paces - Between Saturdays 2 and 3, the data from the self-paced Ss were analyzed and served as a basis for determining the total time, and its distribution among frames, that would be used for the fixed-paced presentations.

As discussed in the Introduction, the pace hypothesized to optimize learning effectiveness and efficiency for Ss of a given level of ability is that adopted by students who most rapidly complete the program and perform at a high level on the criterion test. In this experiment, the determination of such a pace was made for only the lower and upper halves of the sixth-grade ability distribution. The pace chosen as optimal for low-IQ Ss was determined from the self-paced performance of Ss who ranged in IQ from 86 to 108. An optimal pace for high IQ Ss was estimated from the self-paced performance of a group whose IQ-range was between 109 and 131. The hypothetical optimal pace described earlier (see Fig. 1, page 7) is based upon Ss of a given level of ability. Since each IQ grouping in this experiment included a fairly broad range of ability, the optimal pace selected within each was, necessarily, an approximation designed to apply for the entire group. Thus the pace selected as optimal in this case for each ability grouping was probably faster, for the lowest-IQ Ss, than would have arisen from a group of equally low-ability Ss. By the same token, the pace was probably slower, for the highest IQ Ss, than would have arisen from a group of equally high-ability Ss. Recognizing that the empirical distributions of time vs. achievement are based upon Ss of a wide range of ability, a pace was selected which appeared to correspond to the minimum time required by Ss of each ability grouping to reach their best possible achievement scores.

The distribution of time vs. achievement scores obtained from 64 low-IQ Ss who adopted their own pace ($S/I_{Low}$ & $S/G_{Low}$) appears in Fig. 3. Judging from the achievement levels displayed in Fig. 3, 70 percent appeared to be near the maximum possible achievement for this group. The curve shown in Fig. 3 is an estimate of the hypothetical parameter discussed earlier (see Fig. 1, page 7). Judging from the distribution as a whole, the point which appeared most closely to correspond to an "optimal pace" occurred above 157 mins. on the time-to-complete scale. For Ss of this ability range, then, 157 mins. was taken to be the minimum expenditure of time necessary to permit them to obtain their maximum possible achievement scores. Since the median total time spent by these Ss was only 140 mins., it appeared that most of these Ss adopted a work rate that was too fast to permit effective learning.

Figure 4 shows the comparable scatter diagram for the high-IQ group. Comparing it with Fig. 3, it is clear that the overall achievement level was higher for the higher-ability Ss, but that the time distribution was very similar. The median total time spent by the high-IQ group was, in fact, identical to the low-IQ median: 140 mins. Apart from the similarity in median completion time, the high-IQ distribution is quite different. It appears that this group is capable of 90 percent achievement, or better. It also appears that the location of an "optimal pace" on the hypothetical parameter lies to the left of the 140-min. median completion time, at 126 mins. That is, the minimum expenditure of time required for these Ss to achieve 90 percent would be <u>less</u> than was spent by most of them. Thus, it was judged that most of these Ss adopted work rates which were slower than necessary for optimal achievement.

Having selected the optimal total times to employ for the two sixth-grade ability groupings it was necessary, then, to determine the distribution of the total time among each of the 219 frames of the program. The total time to be allotted to the fixed-paced, low-IQ Ss ($F/I_{Low}$ & $F/G_{Low}$) was 157 mins. It was decided, arbitrarily, that 5 secs. be allotted to each confirmation page, or a total of approximately 18 of the 157 mins. to be spent checking answers. That left 139 mins. of working time to be distributed among the 219 frames. From the distributions of time spent on each frame by the 32 $S/I_{Low}$ Ss, a median was calculated for each frame. The median time spent on each frame, divided by the sum of all 219 medians, constituted the proportion of the 139 mins. which was allocated to each frame. In this manner, the total time determined to represent an optimal working pace was distributed among the frames in roughly the same proportion that was allocated to each frame by the low-IQ Ss who had worked under self-paced conditions. This procedure resulted

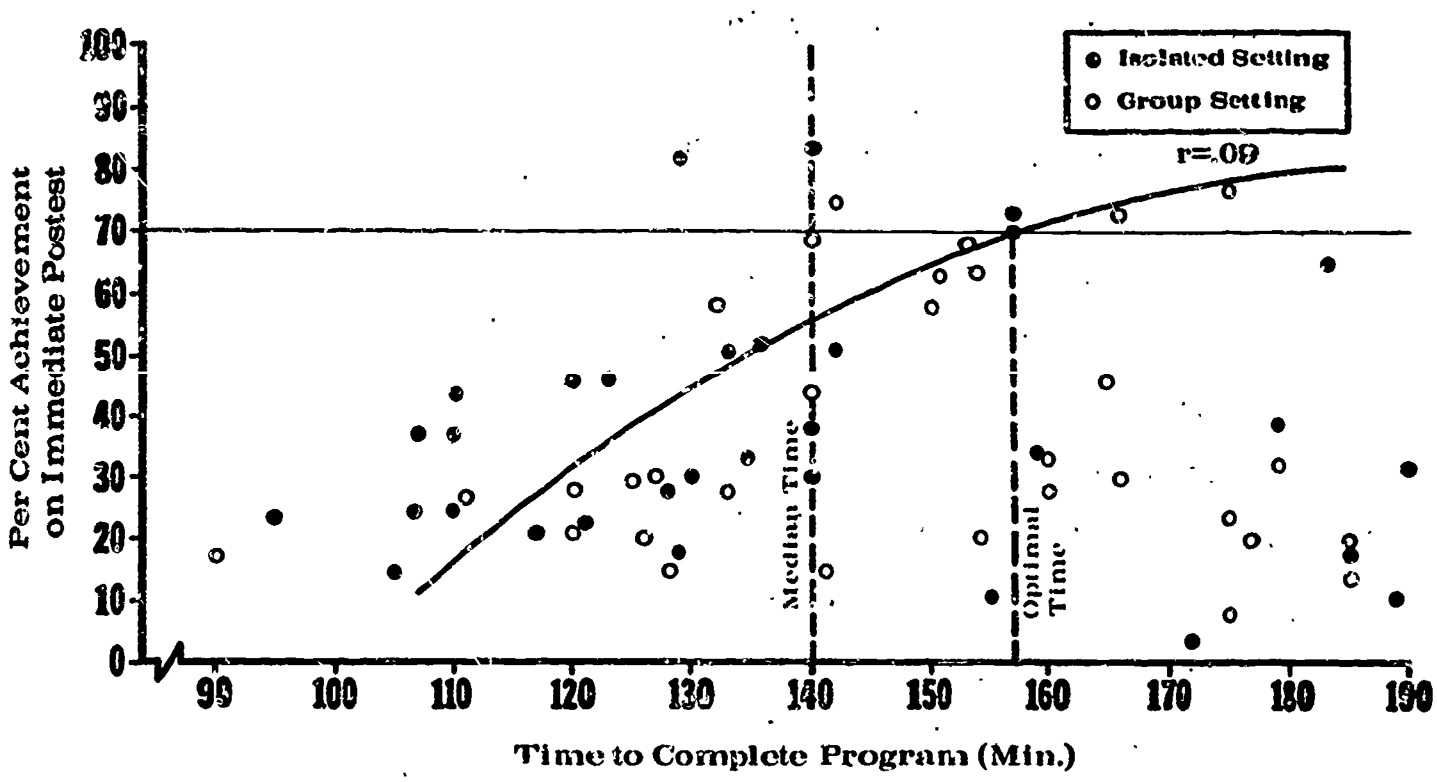


Fig. 3. Scatter diagram of time vs. achievement on the Electrical Circuits Program for 64 low-IQ, sixth graders who worked under self-paced conditions. The curve is a hypothetical parameter of achievement as a function of time spent to complete the program.

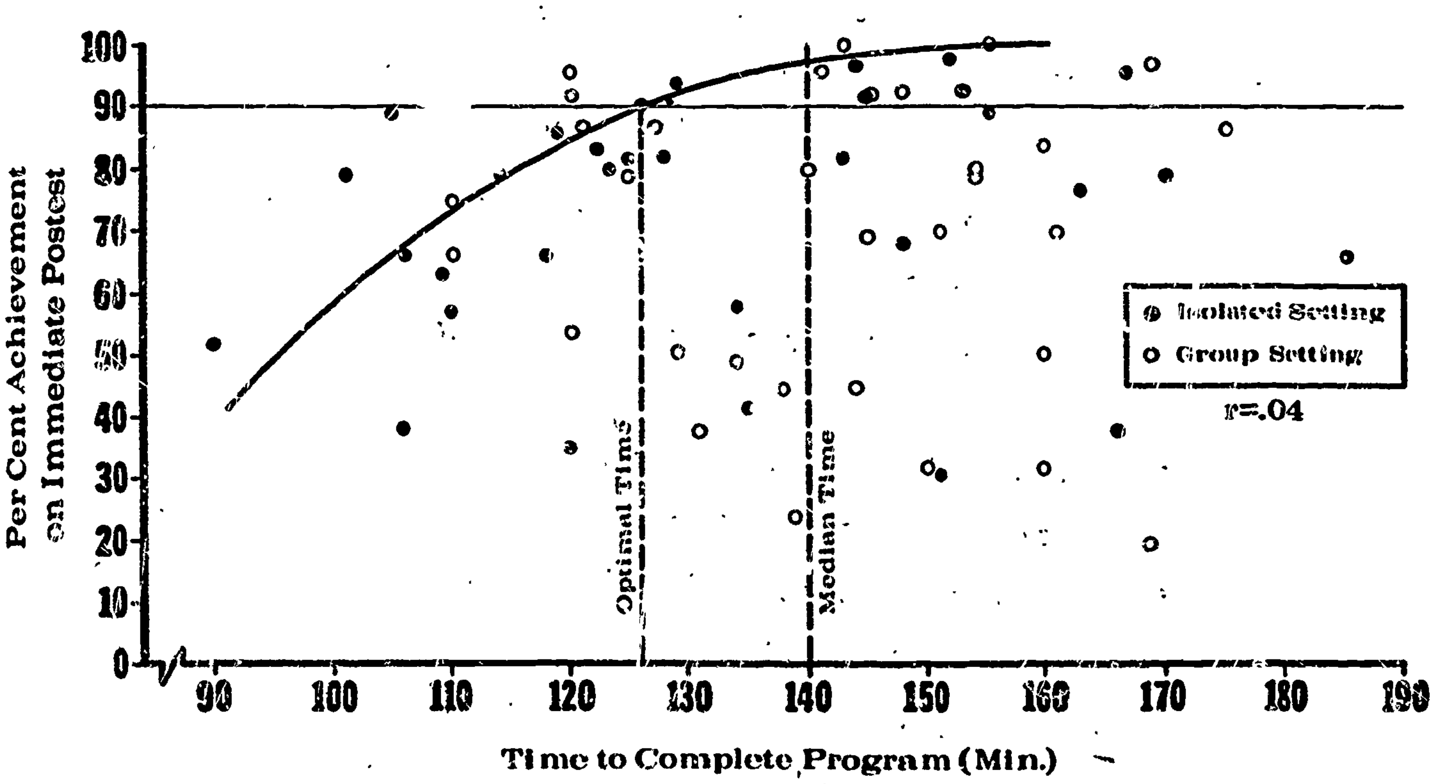


Fig 4. Scatter diagram of time vs. achievement on the Electrical Circuits Program for 64 high-IQ, sixth graders who worked under self-paced conditions. The curve is a hypothetical parameter of achievement as a function of time spent to complete the program.

in a range of time allocations for single frames between 13 secs., for the shortest frame, and 81 secs., for the longest frame. A completely analagous system was followed for the distribution among frames of the optimal total of 126 mins. allocated to the high-IQ Ss in the fixed-paced conditions ($F/I_{High}$ & $F/G_{High}$). It was distributed in roughly the same proportion as was allocated to each frame by the 32 Ss of the $S/I_{High}$ group, with 5 secs. again allotted to each confirmation frame. In this instance, the range of time allocations was between 10 secs., for the shortest frame, and 75 secs., for the longest frame.

The $F/I_{Low}$ Ss were taken to a small room and directed through the program by an E equipped with a stopwatch and list of optimal times per frame. Work began on each frame when E said, "turn to frame ---." When the allotted working time was half elapsed E said, "half." This halfway signal served as a cue to S which was designed to help him budget his reading and writing time on each frame. When the optimal time was fully elapsed E said, "check your answer." Five secs. were allowed for each confirmation page at the end of which E again said, "turn to frame ---" (the next frame in sequence). Break periods were given following frames 76 and 151. The posttest was given immediately as S completed the program.

The $F/G_{Low}$ Ss were seated in a large classroom and each was given a program booklet. They worked, as a group, following pacing instructions identical to those used for the $F/I_{Low}$ except that the direction came from a voice prerecorded on tape. The recorded pacing instructions made use of a bell signal in lieu of the spoken word "half" to indicate the halfway point during each frame. Breaks were given following frames 76 and 151, posttests following completion of the program.

On Saturday 4, the $F/I_{High}$ and $F/G_{High}$ conditions were conducted in a manner completely analogous to the previous week. The differences were that on Saturday 4 the optimal total time was 126 mins. and all Ss were from the high-IQ ability level.

A number of previously absent Ss were run during make-up sessions conducted on the fifth Saturday. Nine Ss were run in the $F/I_{Low}$ condition, 13 were run in the $F/G_{Low}$ condition, and 8 were run in the $F/G_{High}$ condition.

Between 30 and 33 days after taking the Electrical Circuits Progr_m, *Ss* were given the posttest for a second time as a measure of retention. Retention testing was conducted at the various schools, over a period of five weeks, until all Grade 6 treatment groups were contacted.

# RESULTS

The results of the Grade 6 Experiment are based on three separate analyses. The first is an analysis of the overall effects of Pacing Mode, Administrative Setting, and Ability. These effects are assessed by analyses of variance based upon the 2 x 2 x 2 factorial design displayed in Fig. 2. The second analysis deals with the specific effects of the strategy of slowing down low-ability Ss. The third deals with the effects of the strategy of speeding up high-ability Ss. The effects of these two fixed-pacing strategies are assessed by considering the high and low ability levels of the main design separately, and then by a more analytic inspection of results within the particular subgroups whose performance was hypothesized as most likely to benefit from each strategy. The three sets of outcomes will be considered, in order, in the following sections.

The Overall Effects of Pacing Mode, Administrative Setting, and Ability

The random assignment of 256 Ss to treatment conditions resulting in 32 replicates in each of the eight cells of the factorial design (2 types of Pacing x 2 Administrative Settings x 2 Ability levels). Analyses of variance performed on IQ, Pretest scores, and characteristic work rate (on the self-paced, preliminary programs) indicated that the various treatment groups were reasonably well equated on these measures. (These analyses as well as means and S.D.'s for each condition are summarized in Tables 1 through 4 in Appendix B.)

The dependent measures of interest are scores on the Immediate Posttest and Retention Test as well as the number of Errors committed during the program. Also, among the the self-paced Ss, time-to-complete the program was compared for the Group and Isolated settings. For ease of comparison, the four analyses of variance performed for these measures are summarized, together, in Table 2.

(a) Pacing Mode (Self-pacing vs. Fixed-pacing) - As indicated in Tables 2 and 3, a significant difference in Errors was observed between the two pacing modes. Externally fixed pacing (both speeding and slowing) led to the commission of more errors during the program than did self-adopted pacing. Expressed as error rates, the difference was 29 percent for the self-paced group vs. 38 percent for the fixed-paced group ($P < .01$).

Table 2

Summaries of Variance Analyses of
Four Dependent Measures: Grade 6
(N = 256)[1]

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERRORS ELECTRICAL CIRCUITS | Mode | 1 | 1.96 | 32.66** |
| | Setting | 1 | .48 | 6.00* |
| | IQ | 1 | 6.08 | 10.13** |
| | M x S | 1 | .06 | - |
| | M x I | 1 | .15 | 2.48 |
| | S x I | 1 | .00 | - |
| | M x S x I | 1 | .04 | - |
| | Within Replicates | 248 | .06 | |
| POSTTEST ELECTRICAL CIRCUITS | Mode | 1 | 492.29 | 1.14 |
| | Setting | 1 | 3.75 | - |
| | IQ | 1 | 71991.60 | 166.07** |
| | M x S | 1 | 139.54 | - |
| | M x I | 1 | 125.16 | - |
| | S x I | 1 | 242.19 | - |
| | M x S x I | 1 | 335.24 | - |
| | Within Replicates | 248 | 433.50 | |
| RETENTION ELECTRICAL CIRCUITS | Mode | 1 | 1004.04 | 3.53 |
| | Setting | 1 | 156.49 | - |
| | IQ | 1 | 33329.13 | 117.04** |
| | M x S | 1 | 169.46 | - |
| | M x I | 1 | 42.78 | - |
| | S x I | 1 | 44.46 | - |
| | M x S x I | 1 | 554.99 | 1.95 |
| | Within Replicates | 248 | 284.78 | |
| TIME ELECTRICAL CIRCUITS | Setting | 1 | 2932.33 | 5.35* |
| | IQ | 1 | 993.56 | 1.81 |
| | S x I | 1 | .07 | - |
| | Within Replicates | 124 | 548.32 | |

*significant beyond the .05 level

**significant beyond the .01 level

[1] Since Time was free to vary only for the self-paced conditions, the N for that analysis is 128

Table 3

Summary of Number of ERRORS Committed During The Electrical Circuits Program for Each Level of Each Variable[1]
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 112.59 | 71.32 | < .01 |
| | fixed-paced | 147.88 | 74.25 | |
| SETTING | isolated | 141.63 | 77.87 | < .05 |
| | group | 118.84 | 70.01 | |
| IQ | high | 90.66 | 51.31 | < .01 |
| | low | 169.80 | 73.75 | |

[1] Total number of errors possible = 390

Table 4

Summary of Percentage POSTTEST Scores for Each Level of Each Variable
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 54.19 | 27.63 | N.S. |
| | fixed-paced | 51.41 | 25.63 | |
| SETTING | isolated | 52.92 | 25.93 | N.S. |
| | group | 52.68 | 27.42 | |
| IQ | high | 69.57 | 20.35 | < .01 |
| | low | 36.03 | 21.05 | |

Table 5

Summary of Percentage RETENTION TEST Scores for Each Level of Each Variable
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 29.90 | 21.55 | N.S. |
| | fixed-paced | 25.87 | 19.24 | |
| SETTING | isolated | 27.09 | 19.23 | N.S. |
| | group | 28.68 | 21.72 | |
| IQ | high | 39.48 | 21.03 | < .01 |
| | low | 16.29 | 11.37 | |

Table 6

Summary of TIME to Complete the Program (In Mins.) for Each Level of Each Variable
(N = 128)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| SETTING | isolated | 135.86 | 25.22 | < .05 |
| | group | 145.31 | 20.72 | |
| IQ | high | 137.69 | 20.96 | N.S. |
| | low | 143.48 | 25.59 | |

Inspection of Tables 4 and 5 reveals that the superiority of the self-paced groups during the program was followed by slightly higher scores on both Posttest and Retention Test. However, as shown in Table 2, neither difference is significant.

(b) Administrative Setting (Isolated vs. Group Setting) - It may be seen from Table 2 that the setting in which the program was administered also had a significant effect on Errors. The Ss who worked in isolation from their classmates committed more errors than did those who worked in classroom groups. (See Table 3.) The difference in error rates was 36 percent for the isolated Ss vs. 30 percent for the grouped Ss ($P < .05$).

Despite the superiority of the group setting in accuracy during the program, it may be seen in Tables 4 and 5 that Posttest and Retention Test scores were very similar following both settings. Neither difference approached significance.

Table 2 also summarizes the analysis of Time spent by the self-paced Ss to complete the program. That analysis revealed that the group setting led to slower times than resulted from the isolated setting. The difference, 145 vs. 136 mins. (see Table 6), is significant at the .05 level. The fact that isolated Ss adopted faster work rates may explain, at least in part, why they committed more errors during the program.

(c) Ability - From Tables 2 through 5, it is clear that the high-IQ Ss were superior to the low-IQ Ss on Error, Posttest and Retention Test measures. The difference in error rate was 23 percent for the high-IQ Ss vs. 40 percent for the low-IQ Ss ($P < .01$); in Posttest, 70 percent (high) vs. 36 percent (low) ($P < .01$); in Retention, 39 percent (high) vs. 16 percent (low) ($P < .01$).

The one measure which failed to differ significantly as a function of ability was that of time taken to complete the program. This outcome, of course, verified similarities which were evident in the scatter diagrams presented earlier in Figs. 3 and 4. While the mean time taken to complete the program was somewhat shorter for the more capable students, the general pattern was such as to make clear that the self-adopted work rates of these students bore little relation to their ability to learn.

While a number of significant main effects were noted within the set of analyses summarized in Table 2, on no measure did an interaction approach statistical significance. Considering both low and high IQ students, then, the observed effects of each independent variable appeared to be fairly uniform.

Table 7

Summary Analyses of Variance of the Performance of Low-IQ, Sixth Graders (N = 128)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERRORS RELATIVITY | Mode | 1 | 1.52 | 20.27** |
| | Setting | 1 | .26 | 3.45 |
| | M x S | 1 | .09 | 1.22 |
| | Within Replicates | 124 | .08 | |
| POSTTEST RELATIVITY | Mode | 1 | 60.50 | - |
| | Setting | 1 | 153.13 | - |
| | M x S | 1 | 11.13 | - |
| | Within Replicates | 124 | 451.90 | |
| RETENTION RELATIVITY | Mode | 1 | 316.16 | 2.55 |
| | Setting | 1 | 17.06 | - |
| | M x S | 1 | 668.90 | 5.39* |
| | Within Replicates | 120 | 124.15 | |

Table 8

Performance Summaries of Treatment Groups of Low-IQ, Sixth Graders (N = 124)

| | Levels of Independent Variables | | Mean | Sign. Level |
|---|---|---|---|---|
| ERRORS RELATIVITY | Mode | self-paced | 150.78 | .01 |
| | | fixed-paced | 188.81 | |
| | Setting | isolated | 183.48 | N.S. |
| | | group | 156.11 | |
| POSTTEST RELATIVITY | Mode | self-paced | 36.72 | N.S. |
| | | fixed-paced | 35.34 | |
| | Setting | isolated | 37.13 | N.S. |
| | | group | 34.94 | |
| RETENTION RELATIVITY | Mode | self-paced | 17.89 | N.S. |
| | | fixed-paced | 14.69 | |
| | Setting | isolated | 15.92 | N.S. |
| | | group | 16.66 | |

The Effects of Slowing Low-IQ Students

Since the fixed pace employed for high-IQ Ss was designed to be a speed-up and that employed for low-IQ Ss was designed to be a slow-down, the two ability levels were analyzed separately so as to clarify the effects of the two different operations. The former was, of course, designed to maximize learning efficiency, the latter to maximize learning effectiveness.

(a) Analysis of variance results for low-IQ Ss - The analysis of variance summaries and means for each low-IQ treatment combination are presented in Tables 7 and 8.

The most general pattern discernable from these analyses is that, contrary to expectation, forcing sixth-grade students to spend more time on the program failed to enhance their performance. On the contrary, the self-paced group tended to be superior on all three dependent measures. The superiority in Errors was significant ($P < .01$), while that in Posttest and Retention failed to reach significance.

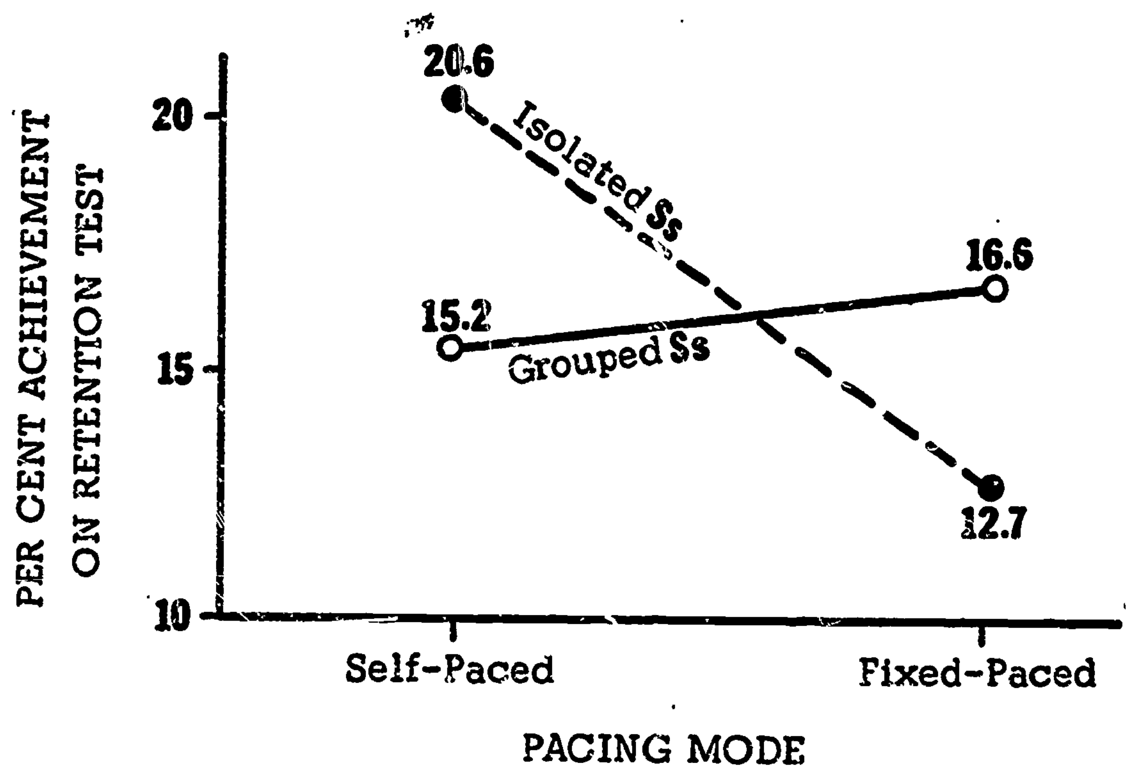


Fig. 5. Mode x Setting interaction for Retention scores among low-IQ Ss.

Although there were no significant main effects in the Retention measure, a significant Mode x Setting interaction ($P < .05$) did occur. The interaction, displayed graphically in Fig. 5, indicates that the superior retention of self-paced Ss occurred only among Ss who worked in isolation. That is, the grouped Ss ($S/G_{Low}$ & $F/G_{Low}$) obtained very similar scores under both pacing modes, while for isolated Ss ($S/I_{Low}$ & $F/I_{Low}$), the fixed pace produced substantially lowered Retention scores. This finding is rather surprising since no evidence of such an interactive effect is present in either Errors or Posttest; mean Posttest scores of the $S/I_{Low}$ and $F/I_{Low}$ groups were virtually identical. It will suffice, then, to say that, while forcing these students to work at a slow pace was generally not successful, it was particularly unsuccessful as measured by the retention scores of Ss who worked in isolation.

(b) Performance of various subgroups among the slowed Ss - It is of further interest to consider the outcome of the slowing strategy with respect to particular subgroups. From the earlier discussion of optimal pacing (see pages 6 and 7), it will be recalled that the imposition of a slow pace is aimed primarily at those Ss, the fast-working, low achievers, whose habitual self-adopted pace is relatively rapid despite high error rates and low achievement. On the other hand, other types are less likely to benefit from a slow fixed pace, e.g., Ss who perform well despite a rapid self-adopted work rate (fast-working, high achievers).

The various types of Ss, among those who worked at a fixed pace, were identified, a priori, so that the effects of the slowing strategy on each type could be analyzed. Using performance scores obtained by self-paced Ss on the Electrical Circuits Program, a prediction equation was generated for each dependent variable. Predictors were selected from among the preliminary measures obtained from all Ss prior to the administration of the Electrical Circuits Program. By placing his appropriate predictor scores in the prediction equations, a predicted score was calculated for every fixed-paced S on Electrical Circuits Program performance measures. Knowing how long he would have spent and what his achievement would have been had he worked under self-paced conditions, it was possible to decide whether S's performance was impaired or enhanced by external pacing.

The predictions were accomplished by performing a series of multiple regression analyses in which eight preliminary measures were considered as predictors of each of the dependent measures obtained by the self-paced Ss on the Electrical Circuits program. These preliminary, predictor measures included: (1) IQ, (2) corrected reading speed (number of items correctly marked on the Tinker Speed of Reading Test), (3) uncorrected reading speed (number of items attempted), (4) sum of pretest scores on the preliminary programs, (5) total time spent to complete the preliminary programs, (6) total errors committed on preliminary programs, (7) total posttest scores on preliminary programs, and (8) score on Electrical Circuits Pretest. The four dependent measures on the Electrical Circuits program, for which multiple regression equations were generated, were: (1) Time to complete, (2) Errors, (3) Posttest, and (4) Retention.

Given the multiple regression weights obtained by that procedure, and the appropriate predictor scores each fixed-paced S had obtained during preliminary sessions, it was possible to calculate a predicted score for each S on each dependent measure. These predicted scores may be described as estimates of the actual scores each S would have obtained, if he had taken the program under self-paced conditions. It was then possible to compare predicted (self-paced) scores with actual scores obtained under fixed-paced conditions, and assess the effects of fixed pacing on the performance of each individual.

A separate set of regression equations was generated for isolated and grouped Ss. All of these multiple regression analyses are summarized in Tables 5 through 12, Appendix B.

In order to provide an overview of the effects of the slow-down on the 64 low-IQ Ss who were submitted to it, a scatter diagram was plotted of predicted time vs. predicted achievement scores. The data points on this diagram, displayed in Fig. 6, reveal the particular work rate and achievement pattern predicted for each S. For example, a point falling in the lower left-hand quadrant represents a fast-working, low achiever; a point falling in the upper right-hand quadrant represents a slow-working, high achiever. To each data point is attached an arrow which traces the difference, up or down, between predicted (self-paced) and obtained (fixed-paced) Electrical Circuits Posttest scores. An upward arrow indicates that the slowing strategy resulted in enhanced performance for that S. The downward arrows, of course, indicate performance decrement.

Inspection of Fig. 6 clarifies a number of facts. First, about as many Ss were impaired by the slow-down as were helped by it. Second, the tendency for gain or loss seems not to be different for different subgroups. Third, while a fair number of Ss fall in the lower left-hand corner of the diagram -- Ss predicted to have been fast-working, low achievers if allowed to pace themselves -- they show no strong tendency toward higher achievement from the forced slow-down.

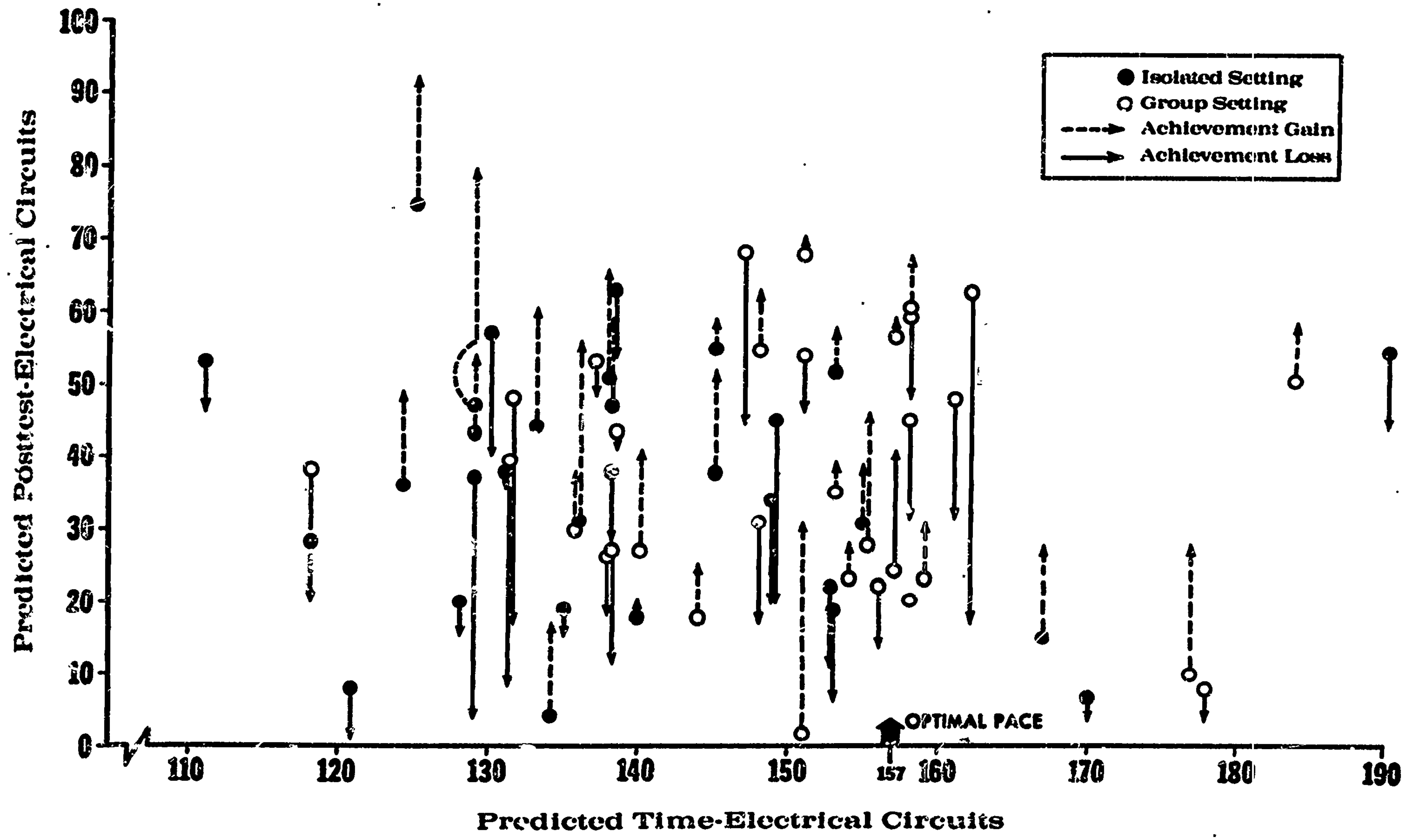


Fig. 6. Scatter diagram of predicted time vs. predicted achievement scores for 64 low-IQ, sixth graders who took the program under slow fixed-paced conditions. Arrows end at actual posttest scores obtained. Fixed time provided (optimal pace) for all Ss was 157 mins.

A more detailed analysis of outcomes for this group of Ss was accomplished by selecting those 18 Ss from the group who were predicted to be the fastest-working, lowest achievers and analyzing differences between their predicted and obtained scores on each dependent measure. The results of the t-tests, summarized in Table 9, verified that: (1) the fixed pace was slower than their normal pace ($P < .01$), (2) they committed slightly fewer errors, (3) they achieved somewhat higher Posttest scores, and (4) slightly lower Retention scores. None of the latter three differences approached statistical significance.

Table 9

Summary t-test Analyses between Predicted and Obtained Scores of Fast-Working, Low Achievers Grade 6

| Dependent Variable | N | $\bar{D}$* | $\sigma_d$ | t | Sign. Level |
|---|---|---|---|---|---|
| Time | 18 | -30.67 | 7.89 | -3.89 | .01 |
| Errors | 18 | 1.67 | 14.05 | .12 | N.S. |
| Posttest | 18 | -3.44 | 2.82 | -1.22 | N.S. |
| Retention | 15 | .20 | 2.11 | -.10 | N.S. |

* (-) sign indicates that obtained score was greater than predicted score

On the basis of all the foregoing, it seems very clear that the strategy of forcing low-ability sixth graders to spend more time on the program did not result in more effective learning. This outcome is not attributable to a shortage of non-adaptive self pacers in the sample, since a substantial proportion of the group were relatively fast-working, low achievers. However, even when considered by themselves, they displayed only a modest tendency toward improved performance.

The Effects of Speeding High-IQ Students

(a) Analysis of variance results for high-IQ Ss - The outcomes of the speeding procedure for the high-ability Ss are summarized in Tables 10 and 11.

Here again, as measured by all three dependent variables, the general effect of externally-controlled pacing was to impair performance. This was not

## Table 10

Summary Analyses of Variance of the Performance of High-IQ, Sixth Graders
(N = 128)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERRORS RELATIVITY | Mode | 1 | .50 | 10.23** |
| | Setting | 1 | .21 | 4.30* |
| | M x S | 1 | .00 | - |
| | Within Replicates | 124 | .05 | |
| POSTTEST RELATIVITY | Mode | 1 | 556.95 | 1.34 |
| | Setting | 1 | 92.82 | - |
| | M x S | 1 | 453.75 | 1.09 |
| | Within Replicates | 124 | 415.11 | |
| RETENTION RELATIVITY | Mode | 1 | 730.65 | 1.64 |
| | Setting | 1 | 183.88 | - |
| | M x S | 1 | 55.55 | - |
| | Within Replicates | 120 | 445.41 | |

## Table 11

Performance Summaries of Treatment Groups of High-IQ, Sixth Graders
(N = 128)

| | Levels of Independent Variables | | Mean | Sign. Level |
|---|---|---|---|---|
| ERRORS RELATIVITY | Mode | self-paced | 74.39 | < .01 |
| | | fixed-paced | 106.94 | |
| | Setting | isolated | 99.77 | < .05 |
| | | group | 81.56 | |
| POSTTEST RELATIVITY | Mode | self-paced | 71.66 | N.S. |
| | | fixed-paced | 67.48 | |
| | Setting | isolated | 68.72 | N.S. |
| | | group | 70.42 | |
| RETENTION RELATIVITY | Mode | self-paced | 41 [illegible] | N.S. |
| | | fixed-paced | 37.05 | |
| | Setting | isolated | 38.36 | N.S. |
| | | group | 40.69 | |

so surprising in this case, of course, since the fixed pace was designed to force most of these high-IQ Ss to work faster than they normally would. While accuracy during the program was impaired significantly, the impairment in Post-test and Retention failed to reach statistical significance. (See Tables 10 and 11.)

(b) Performance of various subgroups among the speeded Ss - A more detailed description of the outcomes of the speeding strategy is provided by the scatter diagram of predicted time vs. predicted achievement for the 64 Ss who worked under fast, fixed-paced conditions. This diagram, displayed in Fig. 7, permits observation of the effects of speeding for the various types of Ss. It is evident that the vast majority of the group was indeed forced to work at a faster than normal pace; predicted self-paced completion times were longer than 127 mins. for 47 of 64 Ss. Furthermore, a substantial proportion of the group was predicted to be slow-working, high achievers under self-paced conditions: the type most likely to withstand speeding without performance decrement. A closer look at the diagram reveals that these types, falling in the upper, right-hand section of the diagram, withstood the speed-up without consistently tending toward achievement decrement.

Unlike the situation observed for the slowed Ss there is an area of this diagram which displays a fairly consistent trend. Those Ss (to the left of 126 mins.) appeared to suffer from the fixed pace which, for them, represented slowing rather than speeding.

Two final sets of analyses were conducted for this speeded group. The first consisted of a series of t-tests of differences between predicted and obtained scores for that quarter ($N = 16$) of the group predicted to be the slowest-working, highest achievers. The second set consisted of similar analyses for the 17 Ss who were, in fact, slowed rather than speeded by the optimal pace employed.

The results of the t-tests for the slow, high achievers, summarized in Table 12, were as follows: (1) The fixed pace was faster than their normal pace ($P < .01$), (2) they committed more errors than predicted ($P < .01$), (3) their posttest scores were somewhat, but not significantly, higher than predicted, and (4) their retention was a trifle lower than predicted.

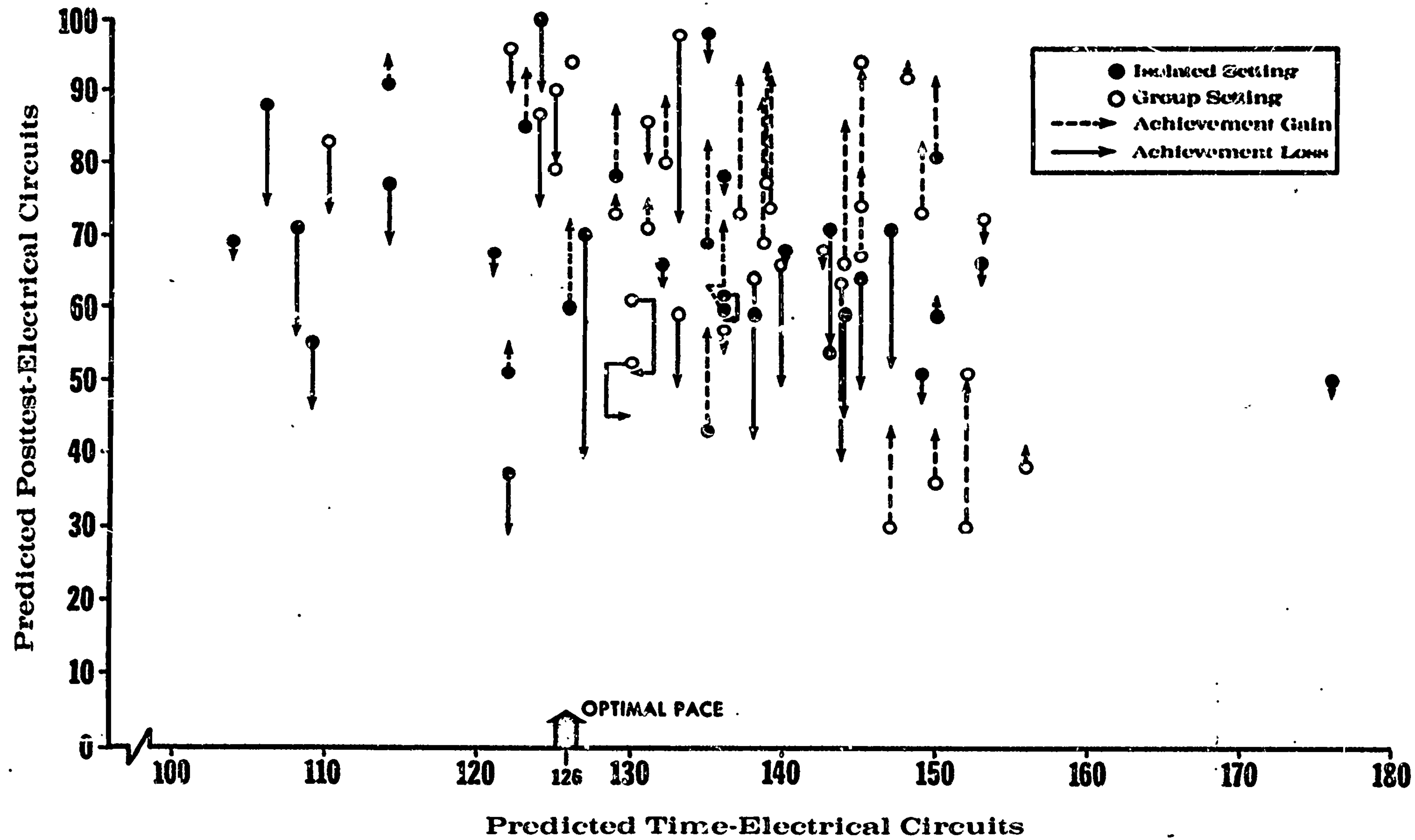


Fig. 7. Scatter diagram of predicted time vs. predicted achievement scores for 64 high-IQ, sixth graders who took the program under fast fixed-paced conditions. Arrows end at actual posttest scores obtained. Fixed time provided (optimal pace) for all Ss was 126 mins.

The results of the t-tests for all Ss whose predicted time was less than 126 mins. are summarized in Table 13. The tests indicated that these Ss: (1) committed more than the predicted number of errors ($P < .05$), (2) achieved lower posttest scores than predicted ($P < .01$), and (3) achieved lower retention scores than predicted ($P < .05$, not significant).

It would appear, taking all of the high-IQ analyses together, that the prospects for maximizing efficiency through pacing are brighter than those for maximizing effectiveness. With two important qualifications, the forced speed-up appears to succeed in shortening learning time without performance decrement. The first is that the fixed pace must, in fact, be faster than the normal pace. Those high-ability students who are slowed by this pace are impaired by it. The second qualification is that the speeding does take its toll in accuracy during the program, despite the fact that no particular decrement is noted in posttest or retention performance.

Table 12

Summary t-test Analyses between Predicted and Obtained Scores of Slow-Working, High Achievers
Grade 6

| Dependent Variable | N | D* | $\sigma_d$ | t | Sign. Level |
|---|---|---|---|---|---|
| Time (min.) | 16 | 17.63 | 1.24 | 14.22 | <.01 |
| Errors | 16 | -32.88 | 10.03 | -3.28 | <.01 |
| Posttest (%) | 16 | -4.81 | 3.51 | -1.37 | N.S. |
| Retention (%) | 16 | 1.31 | 4.51 | .29 | N.S. |

** (-) sign indicates that obtained scores were greater than predicted scores

Table 13

Summary t-test Analyses between Predicted and Obtained Scores of 14 Ss Whose Predicted, Self-Adopted Time was less than 126 min.
Grade 6

| Dependent Variable | N | D* | $\sigma_d$ | t | Sign. Level |
|---|---|---|---|---|---|
| Errors | 14 | -18.21 | 7.78 | -2.34 | <.05 |
| Posttest | 14 | 5.86 | 2.04 | 2.87 | <.01 |
| Retention | 14 | 5.58 | 4.45 | 1.25 | N.S. |

** (-) sign indicates that obtained scores were greater than predicted scores

## Summary: Grade 6 Experiment

The overall effects of each independent variable: Pacing Mode, Administrative Setting and Ability, may be summarized as follows:

(A) Self-pacing resulted in fewer Errors during the program ($P < .05$) than did externally fixed pacing. Self-pacing also led to somewhat, but not significantly, higher achievement as measured by Posttest and Retention Test scores.

(B) Students who worked in group settings spent more time to complete the program ($P < .05$), and committed fewer Errors ($P < .05$), than Ss who worked in isolation. However, virtually no differences were observed between the two settings on either Posttest or Retention Test scores.

(C) High-ability Ss spent somewhat, but not significantly, less time to complete the program than did low-ability Ss. However, they committed fewer errors ($P < .01$), and achieved higher Posttest ($P < .01$) and Retention Test scores ($P < .01$).

The results of the fixed-paced strategy designed to force low-IQ Ss to slow down were as follows:

(A) The slow fixed pace led to impaired, rather than enhanced performance as compared to self-pacing. Fixed-paced Ss committed more Errors ($P < .01$) and achieved somewhat lower Posttest (N.S.) and Retention Test scores (N.S.).

(B) The distribution of predicted time vs. predicted achievement scores revealed that a substantial proportion of the fixed-paced Ss could be described as habitually fast-working, low achievers. However, a set of t-tests of the differences between predicted and obtained achievement scores revealed that even these Ss failed to perform above their predicted self-paced levels.

The results of the fixed-paced strategy designed to force high-IQ Ss to work faster were as follows:

(A) The fast fixed pace led to higher Error rates ($P < .01$), lower Posttest (N.S.), and lower Retention Test scores (N.S.).

(B) The distribution of predicted time vs. predicted achievement scores revealed that 17 of 64 Ss were slowed rather than speeded by the fixed pace employed. Further analyses revealed that the performance of the 47 <u>speeded</u> <u>Ss</u> was not, with the exception of Errors, impaired by the fixed pace. The 17 <u>slowed</u> <u>Ss</u>, on the other hand, displayed substantial impairment from the fixed pace.



ERIC

# GRADE 12 EXPERIMENT

One of the principle concerns of this study was to compare the efficacy of the self-pacing strategy and, consequently, the prospects for improving programmed learning through externally controlled pacing -- at widely separated grade levels. To this end, the experiment conducted at Grade 6 was replicated at Grade 12. This second experiment is described in the following sections.

## METHOD

### Subjects

The sample of Ss who participated in this experiment consisted of 298 twelfth graders. The sample was drawn from four Pittsburgh area high schools, two public and two parochial.

### Materials

As in the sixth-grade study, two short preliminary lessons were administered in the schools prior to the main experiment. A third, longer program was administered under one of the several treatment conditions at an experimental site. New topics were used for the twelfth-grade programs because the subject matter of the sixth-grade programs was likely to be quite familiar to the older students. The topics chosen for the twelfth-grade programs, sub-atomic particle behavior and relativity theory, were selected because it was felt that they could be programmed for students of varying science backgrounds and yet represent new learning, even for students who had taken high-school physics courses.

Preliminary programs - Two programs on the nature and behavior of sub-atomic particles were administered to the entire sample in their classrooms. Their purpose was to familiarize Ss with the programmed format and to provide measures of students' characteristic, self-adopted work rates, error rates, and achievement levels on self-paced programs. Both programs were reproduced in horizontal-book format with three rows of frames per page and confirmation frames on the following page. The programs -- 93 and 72 frames long -- were linear, requiring constructed responses. Sample frames and achievement tests are reporduced in Appendix A.

All preliminary tests and programs were administered to Ss in their respective classrooms during three separate visits which were spaced over a two-week period. The preliminary procedure was thus very similar to that followed during the sixth-grade experiment. The general order and spacing of these sessions is indicated in Table 14. While the order of administration was identical for all Ss, the intertask delay intervals varied so as to accommodate scheduling requirements of the various schools.

Table 14

Schedule of 12th Grade Preliminary Sessions

| Day | Tasks | Approximate Length of Session |
|---|---|---|
| 1 | Pretests on Subatomic Particles I and II, and Relativity Programs and the Tinker Speed of Reading Test | 1-1/2 hrs. |
| | 2 - 13 day delay | |
| 2 | Subatomic Particles I Program and Posttest | 1-1/2 hrs. |
| | 3 - 13 day delay | |
| 3 | Subatomic Particles II Program and and Posttest | 1-1/2 hrs. |

Experimental program - The program used during the experimental sessions was a 204-frame lesson on Einstein's Special Theory of Relativity. It dealt with the following concepts: frames of reference, the constancy of the velocity of light, the relativity of motion, time and distance, and some differences between Classical and Relativistic physics. Sample frames and the criterion test are presented in Appendix A.

All three programs underwent several stages of revision on the basis of tryouts with twelfth-grade students.

## Experimental Design

The design of the Grade 12 Experiment was identical to that employed in the Grade 6 Experiment. The sample was divided into high and low-IQ levels and Ss were assigned randomly, within each level, to one of the four treatment groups designated as: S/I (self-paced, isolated setting), S/G (self-paced, group setting), F/I (fixed-paced, isolated setting), and F/G (fixed-paced, group setting). This resulted in a 2 x 2 x 2 factorial design like the one described earlier and illustrated in Fig. 2, page 10. An analysis of variance of IQ confirmed a highly significant difference between levels ($P < .01$); high-IQ mean = 122, low-IQ mean = 102 (See Tables 13 and 14, Appendix B).

The independent variables were: Pacing Mode, self vs. fixed; Administrative Setting, group vs. isolated; and Ability, high vs. low IQ.

The dependent measures were: number of Errors committed during the program, Immediate Posttest, and Retention Test scores. For those Ss who were run under self-paced conditions, Time taken to complete the lesson was again free to vary as a dependent measure.

Procedure

The procedure employed during this experiment was very similar to that described for the sixth-grade experiment. All experimental sessions were conducted on Saturdays at the offices of A·I·R; the entire sequence required four successive Saturdays for completion. A detailed description of the procedure employed under each condition is identical to the one summarized earlier for the sixth-grade experiment. (See pages 11 and 12.)

Selection of optimal fixed paces - As in the previous experiment, two fixed paces were selected as being optimal, one for the high and one for the low-IQ portions of the sample. They were selected on the basis of an inspection of the scatter diagrams of time vs. achievement on the experimental program, which were based on data obtained from the self-paced Ss during the first two weeks of the experiment. The time vs. achievement data observed from the 44 low-IQ Ss who adopted their own pace ($S/I_{Low}$ & $S/G_{Low}$) is given in Fig. 8.

Inspection of the distribution in Fig. 8 reveals a rather different situation than was observed for low-IQ sixth graders. (See Fig. 3, page 14.) The slower-working twelfth graders did not tend to achieve higher posttest scores. Thus, it was not so clear that a particular slow pace might raise the achievement level of these students. The point chosen as "optimal" on the hypothetical parameter corresponded to 110 mins. on the time scale. This was the fastest time in which a student of less-than-100 IQ was able to complete the program and obtain maximum achievement which, in this case, was 85 percent.

Figure 9 displays the comparable scatter diagram for the high-IQ group. Comparing it with Fig. 8, it may be seen that overall achievement was higher for the high-ability Ss. The amount of time spent to complete the program also differed: the median for high-IQ Ss was 82 mins., while for low-IQ Ss, the median was 95 mins. It will be recalled that at Grade 6, the median time score was identical for both ability levels. Many of the high-IQ twelfth graders achieved posttest scores in excess of 90 percent, following a wide range of completion times. However, the minimum time which appeared necessary to achieve 90 percent was only 60 mins. and this was taken to be "optimal."

Having selected the optimal total time to employ at each ability level, it was again necessary to distribute that total among the 209 frames of the program. As before, this was accomplished by using the per-frame time data recorded from the 22 Ss, of each ability level, who worked under self-paced conditions in the isolated setting (S/I). The median time spent on each frame by the self-paced Ss was expressed as a proportion of the sum of all these medians. Five seconds were again allocated to each confirmation frame, so that approximately 17 minutes of the optimal total times were devoted to the check pages. The remaining time was distributed among the frames in the proportions calculated for each frame from the data of the self-paced Ss. Times allowed per frame varied between 10 and 49 secs. for the low-IQ Ss, and between 3 and 25 secs. for the high-IQ Ss.

Conduct of the fixed-paced sessions - On Saturday 3, all low-IQ Ss assigned to fixed-paced, isolated and fixed-paced, group conditions were run at the slow (110 mins.) fixed pace. The $F/I_{High}$ and $F/G_{High}$ conditions were run on Saturday 4, at the fast (60 mins.) pace. The details of these procedures may be found on page 15 where they are described for the sixth-grade experiment.

All Ss were given the Relativity Posttest as soon as they finished the program. The same test was administered for a second time as a measure of retention. Retention testing was conducted at the various schools during two periods, 30-33 days following Saturday 1, and 30-33 days following Saturday 3.

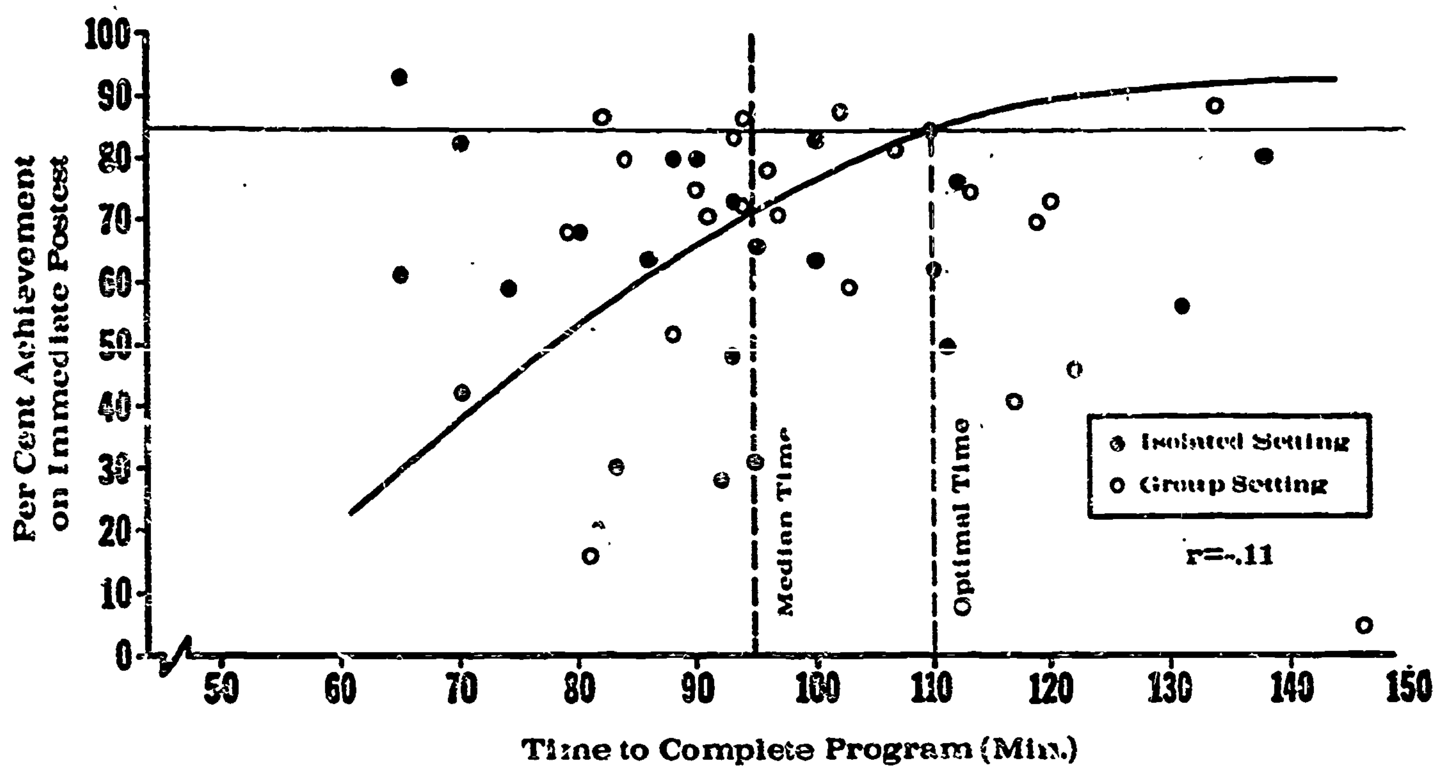


Fig. 8. Scatter diagram of time vs. achievement on the Relativity Program for 44 low-IQ twelfth graders who worked under self-paced conditions.

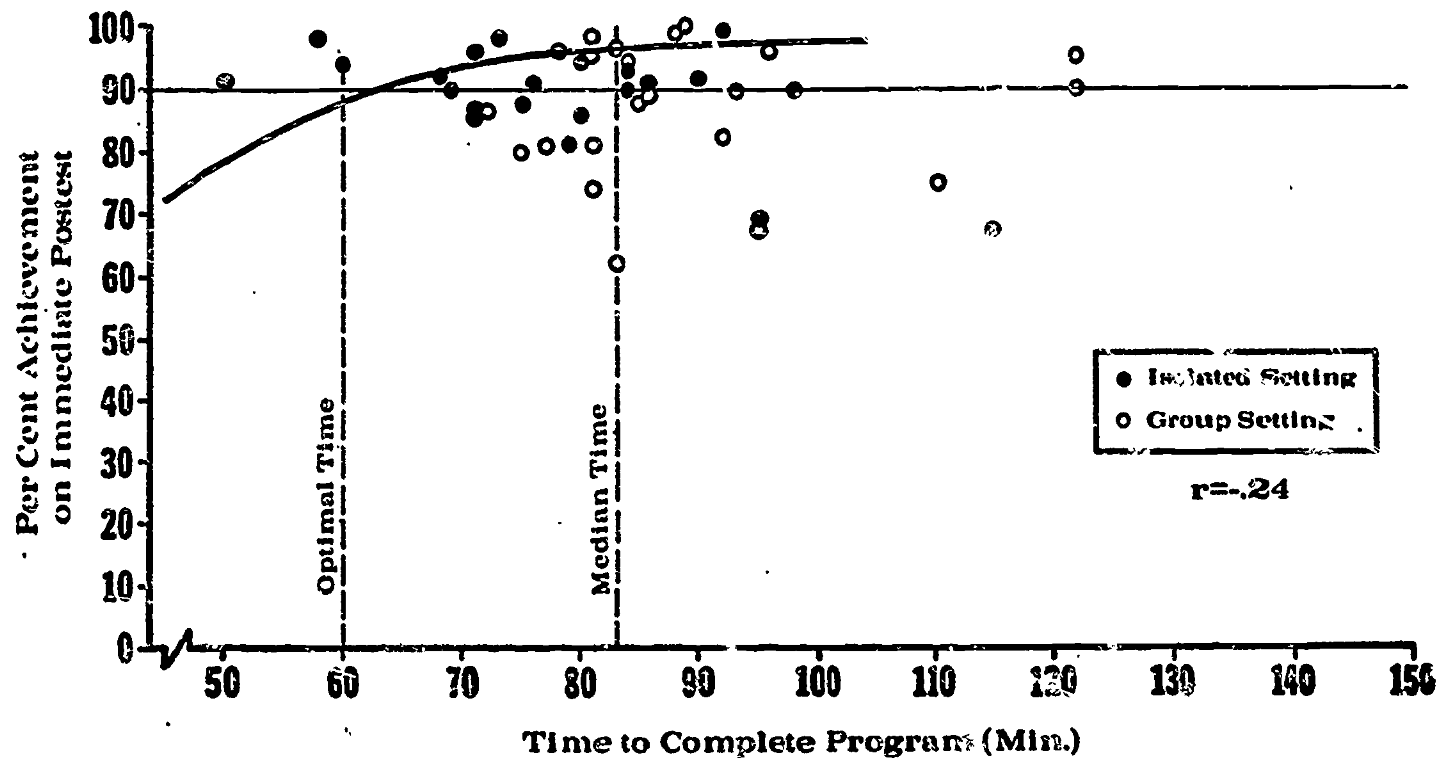


Fig. 9. Scatter diagram of time vs. achievement on the Relativity Program for 44 high-IQ twelfth graders who worked under self-paced conditions.

Because of administrative difficulties, it was not possible to test everyone at equal delay intervals. This meant that for the Ss run on Saturdays 1 and 3, the delay was 30-33 days, but for those run on Saturdays 2 and 4, the delay was only 23-26 days. The average delay interval was thus comparable among both Setting and Pacing Mode conditions, but the high-IQ, fixed-paced group was tested systematically sooner (three weeks vs. four weeks) than the low-IQ, fixed-paced group. Therefore, any superiority to be found for the high-IQ groups in Retention score may be partly attributed to the fact that they were retested sooner.

# RESULTS

The results of the twelfth-grade experiment will be presented in a manner analogous to that employed to summarize the previous, sixth-grade experiment. Separate sets of analyses will be described which deal with: (1) the overall effects of Pacing Mode, Setting, and Ability, (2) the specific effects of optimizing the pace for all low and high ability Ss, and (3) the effects of optimal paces on the particular subgroups of Ss hypothesized as most likely to benefit from that procedure.

In addition to the summaries of twelfth-grade results, comparisons will be made of the results of the two experiments. The purpose of these comparisons will be to assess the role of grade level on the relative abilities of students to adopt work rates which are adaptive and, consequently, the degree to which programmed learning may be improved by externally controlled pacing for students at the lower and higher grade levels.

The Overall Effects of Pacing Mode, Setting, and Ability

The effects of each independent variable in the 2 x 2 x 2 factorial design (see Fig. 2, page 10) were again assessed by analysis of variance techniques. The experimental sample consisted of 176 Ss with 22 replicates per cell. To test for the results of the random assignment of Ss to treatment conditions, analyses of variance were again performed on IQ, Pretest scores, and characteristic Work Rate (on the self-paced preliminary programs). These analyses are summarized in Tables 13-16 in Appendix B. As was the case in the sixth-grade experiment, the various groups appeared reasonably well equated on these measures. The high-IQ level was again different on Pretest and Work Rate than the low-IQ. The one significant failure of the randomization procedure to equate the groups occurred on Work Rate among the high-IQ Ss. Table 13-B reveals that a significant Mode x Setting x IQ interaction exists for Work Rate. Inspection of the cell means indicated that those high-IQ Ss assigned to the F/I and S/G conditions were slower workers than those assigned to the S/I and F/G conditions.

The dependent measures of primary interest are scores on Immediate Posttest and Retention Test as well as Errors committed during the program. Time to complete the program was again free to vary among the self-paced Ss. Four analyses of variance based on these dependent measures, are summarized in Table 15.

(a) Pacing Mode (fixed vs. self) - From Table 16, it may be seen that fixed-pacing resulted in more errors than self-pacing. The difference, in rates of error, was 22 percent for fixed-paced Ss vs. 17 percent for self-paced Ss ($P < .01$).

The superiority of the self-paced groups during the program was accompanied by somewhat higher Posttest and Retention Test scores. (See Tables 17 and 18.) While the difference in Posttest means was not significant, that in Retention was significant beyond the .01 level. (See Table 15.)

The effects of Pacing Mode observed at Grade 12 are thus quite consistent with those observed at Grade 6. Self-paced Ss at both grade levels were more accurate during the program and tended to perform better on criterion tests. At both grades, however, the differences between self and fixed-paced Ss on the posttest measure failed to be statistically significant. Only at Grade 12 did self pacing lead to significantly better Retention scores.

(b) Administrative Setting - From Table 16, it is evident that the setting in which the program was administered again had an effect on Errors. The mean error rate for the isolated Ss was 22 percent vs. 17 percent ($P < .01$) for those who worked in groups. (See Table 15.)

As was the case at Grade 6, the superior accuracy of the grouped Ss during work on the program was not accompanied by a significant difference in either Posttest or Retention Test scores. (See Tables 15, 17, and 18.)

Table 15 also summarizes the analysis of Time spent by the self-paced Ss in completing the program. As was the case at Grade 6, the group setting again led to longer completion times than occurred in the isolated setting. The difference in this case, 95 vs. 86 mins., is significant at the .01 level. (See Tables 15 and 19.)

The fact that the isolated Ss adopted faster work rates is consistent with, and may account for, the fact that they were less accurate during the program. An alternative explanation might be that, since isolated Ss were much more closely monitored than were the grouped Ss, they had less opportunity to read ahead and copy correct responses from confirmation pages. Although the grouped Ss were monitored, there was not an E for every S as was the case in the isolated situation.

Table 15

Summaries of Variance Analyses of
Four Dependent Measures: Grade 12
(N = 176)[1]

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERROR RELATIVITY | Mode | 1 | 1.18 | 28.80** |
| | Setting | 1 | .94 | 28.00** |
| | IQ | 1 | 3.23 | 81.00** |
| | M x S | 1 | .02 | - |
| | M x I | 1 | .76 | 18.50** |
| | S x I | 1 | .03 | - |
| | M x S x I | 1 | .03 | - |
| | Within Replicates | 168 | .04 | |
| POSTTEST RELATIVITY | Mode | 1 | 589.13 | 2.34 |
| | Setting | 1 | 34.59 | - |
| | IQ | 1 | 22185.12 | 88.29** |
| | M x S | 1 | .00 | - |
| | M x I | 1 | 43.98 | - |
| | S x I | 1 | 10.97 | - |
| | M x S x I | 1 | 295.39 | 1.18 |
| | Within Replicates | 168 | 251.29 | |
| RETENTION RELATIVITY | Mode | 1 | 2768.20 | 9.24** |
| | Setting | 1 | 611.27 | 2.04 |
| | IQ | 1 | 27101.45 | 90.44** |
| | M x S | 1 | 752.82 | 2.52 |
| | M x I | 1 | 76.45 | - |
| | S x I | 1 | 439.11 | 1.47 |
| | M x S x I | 1 | 477.83 | 1.59 |
| | Within Replicates | 168 | 299.68 | |
| TIME RELATIVITY | Setting | 1 | 2091.36 | 7.56** |
| | IQ | 1 | 4131.91 | 14.94** |
| | S x I | 1 | 8.30 | - |
| | Within Replicates | 84 | 276.60 | |

*significant beyond the .05 level

**significant beyond the .01 level

[1] Since Time was free to vary only for the self-paced conditions, the N for that analysis is 88

Table 16

Summary of Number of ERRORS Committed During The Relativity Program for Each Level of Each Variable[1]
(N = 176)

| Levels of Independent Variables | | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 54.36 | 36.05 | < .01 |
| | fixed-paced | 70.58 | 31.94 | |
| SETTING | isolated | 70.34 | 33.14 | < .01 |
| | group | 54.60 | 35.06 | |
| IQ | high | 45.83 | 26.31 | < .01 |
| | low | 79.11 | 34.65 | |

[1]Total number of errors possible = 325

Table 17

Summary of Percentage POSTTEST Scores for Each Level of Each Variable
(N = 176)

| Levels of Independent Variables | | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 76.45 | 19.76 | N.S. |
| | fixed-paced | 72.80 | 18.82 | |
| SETTING | isolated | 74.18 | 19.26 | N.S. |
| | group | 75.07 | 19.50 | |
| IQ | high | 85.85 | 11.17 | < .01 |
| | low | 63.40 | 19.28 | |

Table 18

Summary of Percentage RETENTION TEST Scores for Each Level of Each Variable
(N = 176)

| Levels of Independent Variables | | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 62.05 | 2[illegible].46 | < .01 |
| | fixed-paced | 54.11 | 21.38 | |
| SETTING | isolated | 56.22 | 21.73 | N.S. |
| | group | 59.94 | 21.68 | |
| IQ | high | 70.49 | 15.35 | < .01 |
| | low | 45.67 | 20.05 | |

Table 19

Summary of TIME to Complete the Program (In Mins.) for Each Level of Each Variable
(N = 88)

| Levels of Independent Variables | | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| SETTING | isolated | 85.57 | 18.41 | < .01 |
| | group | 95.32 | 17.26 | |
| IQ | high | 83.59 | 14.83 | < .01 |
| | low | 97.30 | 19.22 | |

(c) Ability - Inspection of Tables 15-19 indicates that high-IQ Ss were again clearly superior to low-IQ Ss on every dependent measure. The difference in error rate was 14 percent vs. 25 percent ($P < .01$); in Posttest, 86 percent vs. 63 percent ($P < .01$); in Retention, 70 percent vs. 46 percent ($P < .01$). The direction of each of these differences parallels that observed at Grade 6.

One major difference between the grade levels is in the effect of Ability upon Time to complete the program. It will be recalled that no significant IQ difference was observed for Time scores of sixth graders. In the case of the twelfth graders, however, the IQ difference was significant. From Table 19, it may be seen that low-IQ Ss spent a mean time of 97 mins. to complete the program vs. only 84 mins. for high-IQ Ss ($P < .01$).

Only one significant interaction occurred in all these analyses: Pacing Mode x IQ in Errors. (See Table 15.) Briefly, this interaction indicates that while little difference in error rate existed between self (23 percent) and fixed-paced (25 percent) low-IQ Ss, a fixed pace for high-IQ Ss led to a substantial increase in error rates, from 10 percent to 19 percent. Thus, the slowing of low-IQ Ss had little effect on their accuracy during the program, whereas the speeding of high-IQ Ss caused a substantial decrease in their accuracy.

The overall effects of each independent variable, then, are highly similar at both grade levels. The one major exception noted was the difference in time taken to complete the program between high and low-ability twelfth graders. It appears that self-adopted work rate is more strongly related to ability at Grade 12 than at Grade 6.

The Effects of Slowing Low-IQ Students

An evaluation was again made of the slowing-up strategy for low-ability Ss by variance analyses. The effects of the strategy on particular subgroups within the low-ability level were again assessed by a multiple prediction procedure completely analagous to that described for the sixth-grade experiment (pages 23 and 24).

(a) Analysis of variance results for low-IQ Ss - The variance analyses for low-IQ Ss are summarized in Table 20. The means of each treatment group on each dependent measure appear in Table 21.

Table 20

Summaries of Analyses of Variance of the Performance of Low-IQ Twelfth Graders (N = 88)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERRORS RELATIVITY | Mode | 1 | .02 | - |
| | Setting | 1 | .31 | 9.56** |
| | M x S | 1 | .05 | 1.57 |
| | Within Replicates | 84 | .03 | |
| POSTTEST RELATIVITY | Mode | 1 | 155.56 | - |
| | Setting | 1 | 42.28 | - |
| | M x S | 1 | 150.28 | - |
| | Within Replicates | 84 | 380.82 | |
| RETENTION RELATIVITY | Mode | 1 | 1882.37 | 4.94* |
| | Setting | 1 | 1043.28 | 2.74 |
| | M x S | 1 | 15.56 | - |
| | Within Replicates | 84 | 381.24 | |

Table 21

Performance Summaries of Treatment Groups of Low-IQ Twelfth Graders (N = 88)

| | Levels of Independent Variables | | Mean | Sign. Level |
|---|---|---|---|---|
| ERRORS RELATIVITY | Mode | self-paced | 70.47 | N.S. |
| | | fixed-paced | 75.86 | |
| | Setting | isolated | 83.96 | < .01 |
| | | group | 63.75 | |
| POSTTEST RELATIVITY | Mode | self-paced | 64.72 | N.S. |
| | | fixed-paced | 62.07 | |
| | Setting | isolated | 62.70 | N.S. |
| | | group | 64.09 | |
| RETENTION RELATIVITY | Mode | self-paced | 50.30 | < .05 |
| | | fixed-paced | 41.05 | |
| | Setting | isolated | 42.23 | N.S. |
| | | group | 49.11 | |



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These analyses reveal that the slowing strategy failed to enhance the performance of the low-ability students. On the contrary, the direction of the differences favored the self-paced group on every measure, although only the difference in Retention was significant ($P < .05$).

The pattern observed among the low-ability twelfth graders is very similar to that observed among their counterparts in sixth grade. At both grade levels, the forced slowdown tended to degrade rather than to enhance their performance. There appeared to be less decrement in accuracy during the program among the older students, but somewhat more decrement in their retention. These minor differences aside, the strategy of prolonging their contact with each frame in the program appears to be equally unsuccessful at Grades 6 and 12.

(b) Performance of various subgroups among the slowed Ss - While the results of the variance analyses summarized above display rather high similarity between the two grade levels, a more detailed inspection of results for subgroups revealed some interesting differences.

Figure 10 displays the scatter diagram of predicted time vs. predicted achievement for each of the 44 low-IQ Ss who worked under the slow, fixed-paced condition. These data points represent estimated time and achievement scores which would have resulted had they worked under self-paced conditions. (The multiple regression analyses and predictor weights based upon 88 self-paced Ss are summarized in Tables 17 through 24, Appendix B.) To each S's data point is connected an arrow which leads to the actual posttest score obtained by that S following the slow, fixed pace. The location of a data point reveals the work rate and achievement pattern predicted for that S, had he been permitted to adopt his own pace. For example, points falling in the lower left-hand quadrant describe fast-working, low achievers. The direction of the arrow connected to each point indicates whether fixed pacing led to higher (upward arrow) or lower (downward arrow) scores than would have resulted from self pacing.

The most apparent feature of the data appearing in Fig. 10 is the relative absence of cases predicted in the lower left-hand quadrant of the diagram; there were few Ss who could be characterized as habitual fast-working, low achievers. This situation contrasts markedly with that observed at Grade 6, where a substantial number of Ss were predicted to be fast, low achievers (see Fig. 6).

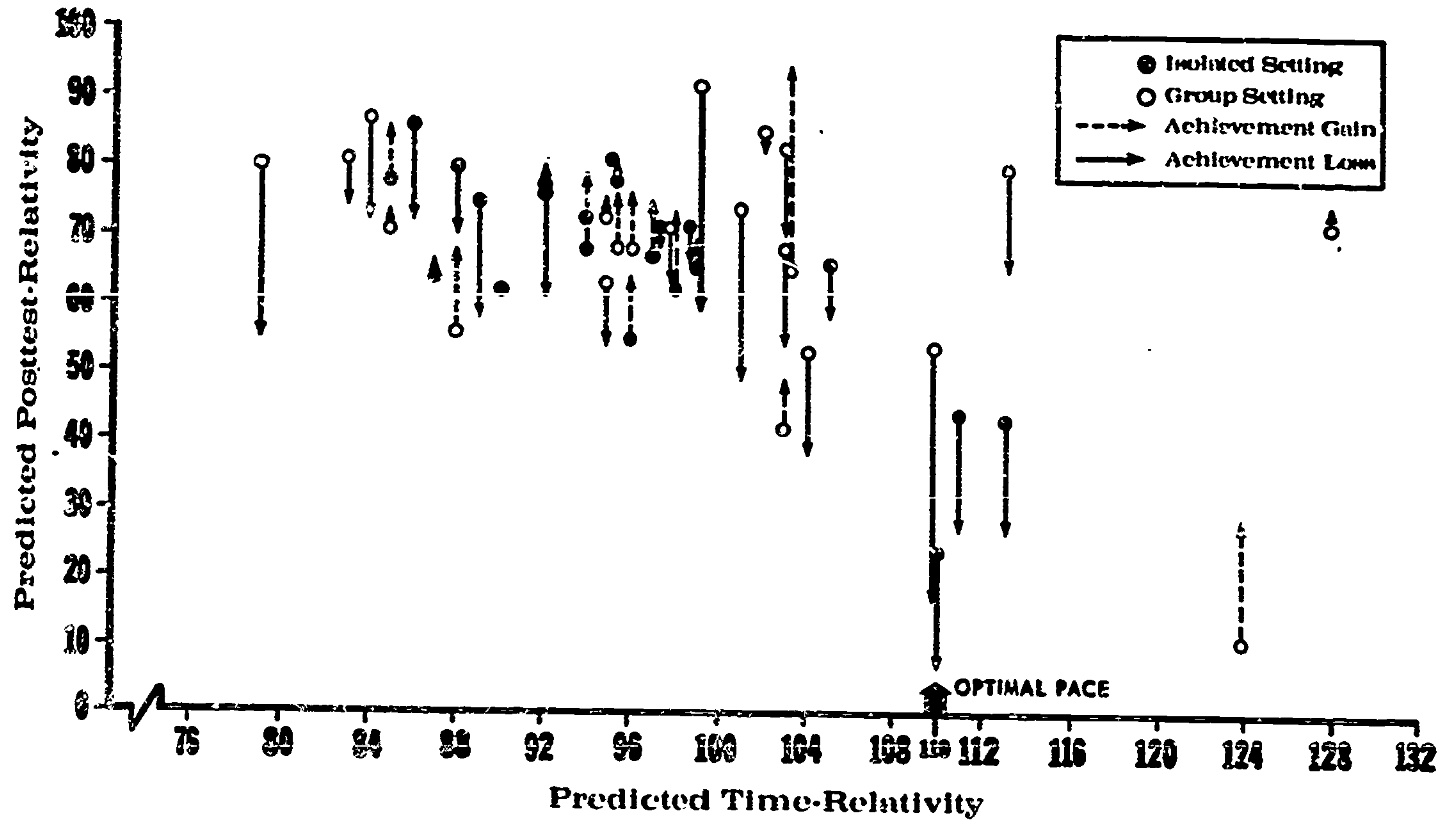


Fig. 10. Scatter diagram of predicted time vs. predicted achievement scores for 44 low-IQ Ss who took the program under slow (110 mins.) fixed-paced conditions. Arrows end at actual posttest scores obtained.

Regarding the direction of the differences, the general trend is for obtained scores to be slightly lower than predicted scores. This, of course, is consistent with the analysis of variance outcome; the slowing strategy failed to enhance posttest scores. Further, that general trend appeared to be fairly uniform over the entire distribution with no particular subgroup benefitting from the slowdown.

Although few students could be characterized as clearly fast-working, low achievers, the ten Ss predicted to be the fastest-working, lowest achievers (had they paced themselves instead of having been slowed down by the fixed pace) were selected for further analysis. This is the group which was hypothesized as most likely to benefit from the slow, fixed pace. A series of t-tests was conducted to assess the differences between their predicted and obtained scores on each measure. The results of these tests appear in Table 22. These analyses indicate that: (1) the fixed pace (110 mins.) was indeed slower than their normal paces ($P < .01$), (2) they committed a somewhat larger number of errors, (3) they achieved somewhat higher Posttest scores, but (4) significantly lower Retention Test scores ($P < .01$).

Table 22

Summary t-test Analyses between Predicted and Obtained Scores of Fast-Working, Low Achievers. Grade 12

| Dependent Variables | N | $\bar{D}$* | $\sigma_d$ | t | Sign. Level |
|---|---|---|---|---|---|
| Time | 10 | -17.25 | 1.44 | -12.15 | < .01 |
| Errors | 10 | -11.80 | 5.46 | -2.16 | N.S. |
| Posttest | 10 | -3.90 | 2.16 | -1.81 | N.S. |
| Retention | 10 | 16.40 | 3.87 | 4.23 | < .01 |

* (-) sign indicates that obtained score was greater than predicted score

To summarize, the strategy of slowing twelfth graders failed to enhance performance even for the fastest-working, lowest-achieving members of the group. To this extent the Grade 6 and Grade 12 findings are quite consistent. At Grade 12, however, there are fewer candidates for this treatment. That is, few low-achieving twelfth graders were habitually fast workers.

The Effects of Speeding High-IQ Students

The final assessment to be made of attempts to achieve an optimal fixed pace concerns the strategy of speeding high-IQ twelfth graders.

(a) Covariance analyses results for high-IQ Ss - Because of the marked imbalance among high-IQ Ss in Work Rate which resulted from the random assignment to treatment conditions (see Table 13, Appendix B), Work Rate (on preliminary programs) was employed as a covariant. Summary analyses and adjusted means appear in Tables 23 and 24.

From these tables, it may be seen that the rapid, fixed pace disrupted performance as assessed by all three dependent measures. All differences noted in the tables favored the self-paced group and every one was statistically significant.

A significant interaction occurred in the Retention measure between Pacing Mode and Administrative Setting. This interaction, plotted in terms of cell means for adjusted Retention scores is displayed in Fig. 11. The superiority

Table 23

Summary Covariance Analyses of the Performance of High-IQ Twelfth Graders. Work Rate (on preliminary programs) was employed as covariant throughout.
(N = 88)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| LOG ERRORS RELATIVITY | Mode | 1 | 2.09 | 38.97** |
| | Setting | 1 | .72 | 13.36** |
| | M x S | 1 | .00 | - |
| | Within Replicates | 83 | .05 | |
| POSTTEST RELATIVITY | Mode | 1 | 520.76 | 4.34* |
| | Setting | 1 | 4.03 | - |
| | M x S | 1 | 40.61 | - |
| | Within Replicates | 83 | 119.97 | |
| RETENTION RELATIVITY | Mode | 1 | 979.91 | 4.45* |
| | Setting | 1 | 7.46 | - |
| | M x S | 1 | 987.62 | 4.48* |
| | Within Replicates | 83 | 220.37 | |

Table 24

Performance Summaries of Treatment Groups of High-IQ Twelfth Graders
(N = 88)

| | Levels of Independent Variables | | Adjusted Mean | Sign. Level |
|---|---|---|---|---|
| ERRORS RELATIVITY | Mode | self-paced | 31.39 | < .01 |
| | | fixed-paced | 60.27 | |
| | Setting | isolated | 65.43 | < .01 |
| | | group | 38.43 | |
| POSTTEST RELATIVITY | Mode | self-paced | 88.29 | < .05 |
| | | fixed-paced | 83.41 | |
| | Setting | isolated | 85.44 | N.S. |
| | | group | 86.27 | |
| RETENTION RELATIVITY | Mode | self-paced | 73.85 | < .05 |
| | | fixed-paced | 67.13 | |
| | Setting | isolated | 70.11 | N.S. |
| | | group | 70.87 | |

in Retention displayed by the self-paced Ss is accounted for completely by the data for self-paced Ss who worked in the isolated setting. That is, the Retention means of the $S/G_{High}$ and $F/G_{Low}$ conditions are practically identical, whereas the Retention mean of the $S/I_{High}$ condition is substantially higher than that of $F/I_{High}$. The implication seems to be that while speeding did impair performance across the board, it was particularly disruptive of the retention of Ss who were speeded in isolation. Curiously, this interaction pattern is almost identical to that detected among sixth graders who were slowed (see Fig. 5, page 22), but appeared in no measure other than Retention at either grade level.

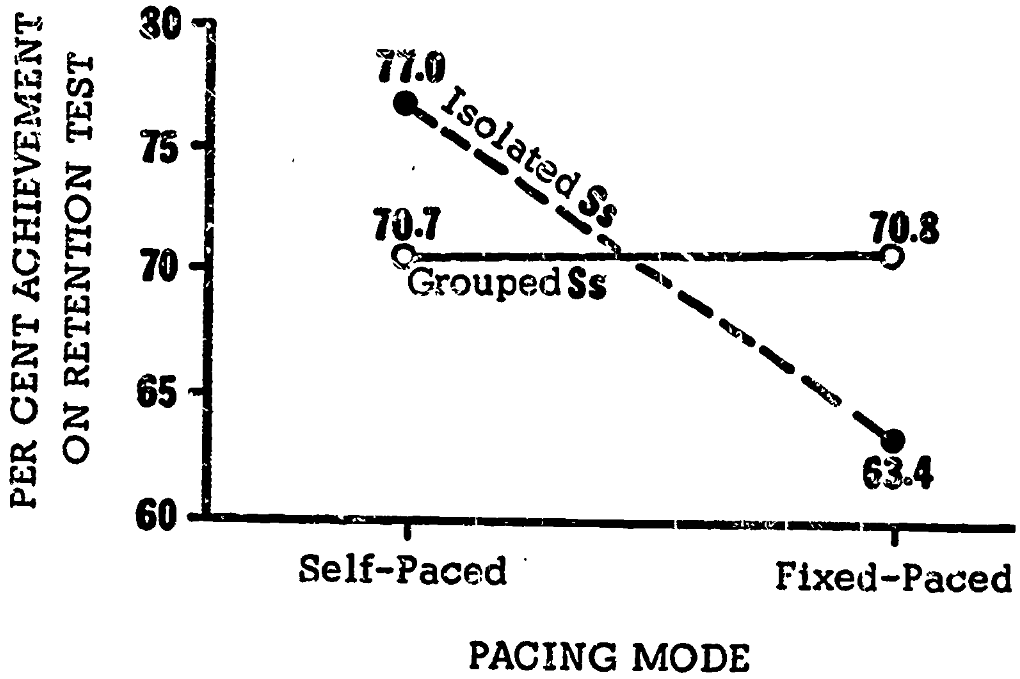


Fig. 11. Mode x Setting interaction in Retention scores adjusted for characteristic work rate.

(b) Performance of various subgroups among the speeded Ss - The scatter diagram of predicted time vs. predicted achievement for each high-IQ S appears in Fig. 12. It is evident from the figure that the optimal pace forced every S to work faster than he would have, if allowed to adopt his own pace. It is also evident that a fair number of high achievers were relatively slow workers (data points falling in upper right-hand portion of the diagram).

The fact that more posttest scores went down than went up (as indicated by the direction of the arrows) confirms that the fast, fixed pace resulted in reduced achievement for this group as a whole. From the upper right-hand portion of the diagram, it appears that the slow, high achievers displayed about as much reduction on posttest scores as all other Ss.

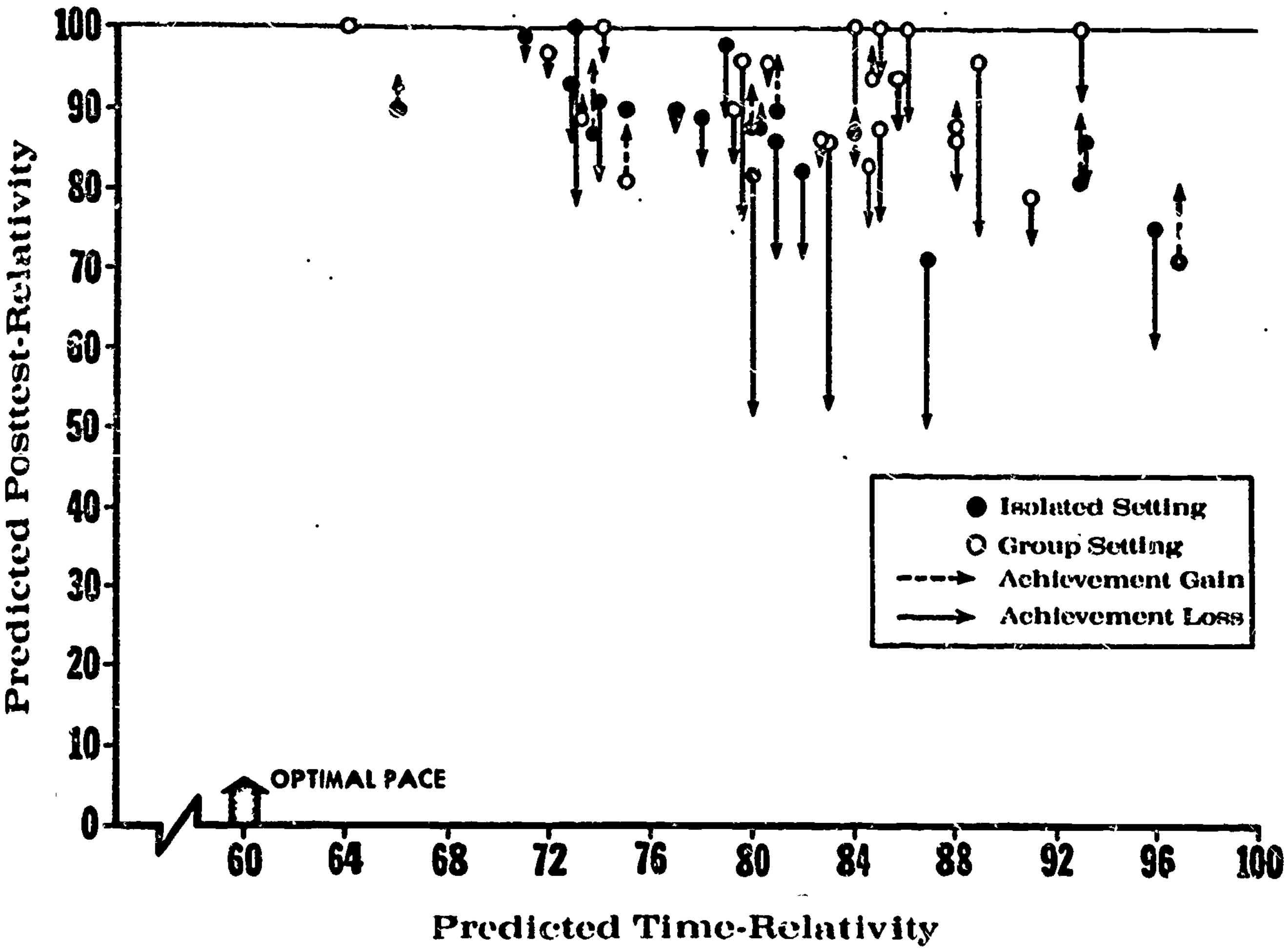


Fig. 12. Scatter diagram of predicted time vs. predicted achievement of 44 high-IQ Ss who took the program under fast (60 mins.) fixed-paced conditions. Arrows end at actual posttest score obtained.

In order to assess the effects of speeding upon this group, 14 Ss were selected who were predicted to be the slowest-working, highest achievers. A series of t-tests were then performed to assess the differences between their scores obtained under the fixed-paced condition and their scores predicted to have occurred if they had worked under self-paced conditions. These tests, summarized in Table 25, revealed that the fixed pace: (1) was indeed faster than their normal pace ($P < .01$), (2) resulted in commission of more errors during the program ($P < .01$), (3) resulted in lower Posttest scores ($P < .01$), and (4) led to a modest, but not significant, reduction in Retention Test scores.

It seems clear, then, that speeding these students was not a successful strategy for optimizing learning since the rapid pace took its toll on every performance measure. The failure of the strategy cannot be attributed to a lack of slow-working, high achievers; there were fair numbers of such students in the twelfth-grade group. Even when considered by themselves, however, their performance decrements were pronounced.

Table 25

Summary t-test Analyses between Predicted and Obtained Scores of Slow-Working, High Achievers. Grade 12

| Dependent Variable | N | D̄* | $\sigma_d$ | t | Sign. Level |
|---|---|---|---|---|---|
| Time | 14 | 26.86 | .80 | 33.58 | <.01 |
| Errors | 14 | -31.29 | 4.92 | -6.36 | <.01 |
| Posttest | 14 | 7.78 | 2.66 | 2.92 | <.05 |
| Retention | 14 | 2.86 | 3.81 | .75 | N.S. |

* (-) sign indicates that obtained score was greater than predicted score

It will be recalled that the speeding strategy appeared to be more successful at Grade 6, where the speeded Ss withstood the fixed pace without significant impairment in criterion-test scores. The observed failure of the speeding strategy at Grade 12 would seem to indicate that these students are less amenable to speeding than are sixth graders. However, it is first necessary to consider whether the degree of speeding brought about by the particular fixed pace employed was the same at both grade levels.

One way to quantify the extent to which students were speeded by the rapid, fixed pace is to express the difference between predicted and actual total time as a percentage of the actual time, resulting in a percentage speedup or time saved for each S. The mean percentage speedup for twelfth graders, calculated on this basis, was 26 percent. And, as noted earlier, it turned out that every S in the fixed-paced conditions was indeed speeded. It will be recalled that the situation at Grade 6 turned out to be rather different. First, 17 of 64 Ss were not speeded by the fixed pace employed. Even considering only those Ss who were speeded, the mean percentage speedup was only 13 percent. It is perfectly conceivable, then, that had the optimal pace represented as modest a degree of speeding at Grade 12 as at Grade 6, the older students may not have suffered significant achievement decrement.

Quite apart from the question of statistical significance, the magnitude of changes brought about by fixed pacing at the two grade levels might be contrasted. Table 26 contains a summary of such changes at each grade level. Two kinds of comparison are made: (1) between self-paced and fixed-paced high-IQ Ss and (2) between the scores predicted for and actually obtained by the fixed-paced Ss. The numbers appearing in Table 26 express the difference between the higher and lower scores as a percentage of the higher. For example, the mean Posttest score for high-IQ sixth graders who worked under self-paced conditions was 71.66 (see Table 11, page 27). For fixed-paced Ss, the mean was 67.48. The difference, 4.18, is 5.8 percent of the higher (71.66) score.

The performance of the fixed-paced sixth graders is closer to their predicted performance than to the performance of their counterparts who worked under self-paced conditions. Apparently the self-paced group, though quite similar in terms of IQ, Work Rate and Pretest, contained somewhat higher achievers.

The magnitudes of decrement appear more similar on both bases of comparison among twelfth graders. And, for the most part, the more extreme degree of speeding at Grade 12 resulted in more pronounced decrements in performance, particularly in Errors.

Table 26

The Effects of the Speeding Strategy at Grades 6 and 12

| Grade | Basis of Comparison | N | Mean Degree of Speeding | Mean Increase in Errors | Mean Decrement in Posttest | Mean Decrement in Retention |
|---|---|---|---|---|---|---|
| 6 | self vs. fixed | 128 | 11.6% | 44% | 5.8% | 11.6% |
| | predicted vs. | 47 | 13% | 44% | -.38%* | 2.77% |
| | obtained | 64 | 6% | 40% | 1.65% | 2.79% |
| 12 | self vs. fixed | 88 | 35% | 92% | 5.5% | 9.1% |
| | predicted vs. obtained | 44 | 26% | 80% | 7.13% | 6.25% |

* (-) sign indicates that obtained scores were higher than predicted in this instance

The Relationships among Ability and Performance Measures at Grades 6 and 12

In addition to the analyses previously described, a complete matrix of correlations was calculated at both grade levels among all ability, preliminary program, and experimental-program variables measured. In all, 20 such measures were obtained at each grade. The variables and complete matrices are presented in Tables 25 and 26, Appendix B. Correlation coefficients obtained for 11 of the 20 variables are included in Table 27. Comparable coefficients from Grades 6 and 12 are presented, side by side in Table 27, for ease of comparison.

Inspection of the table reveals some striking similarities and differences between the two grades. Some of the clearer similarities are the correlations between IQ and the program performance measures of Errors, Posttest, and Retention which appear across the top row of the table. The influence of ability on performance seems to have been rather strong, and about equally so, at both grade levels. Another inter-grade similarity is the nearly equal and quite strong inverse relationship (-.58 to -.75) between errors and achievement on all programs. This implies that accuracy during the program contributed to higher achievement on all programs at both grade levels.

Further inspection of Table 27 reveals that sixth and twelfth graders differ widely with respect to the variables which are related to Work Rate. Interestingly, individual Work Rate (measured by total time to complete a program) was found to be highly stable during both preliminary programs at both grade levels. The value of rho for sixth graders was .775, for twelfth graders, .723 (see Tables 25 and 26, Appendix B). On the other hand, characteristic Work Rate among sixth graders is less strongly related to IQ than is the case among twelfth graders: -.38 vs. -.62. While it is not possible to assess the statistical significance of the difference between these coefficients, it is reasonable to suspect that they arise from substantially different relationships between Work Rate and ability at the two grade levels.

Further evidence of the disparate roots of self-adopted work rates at the two grade levels appears in the column under Time (to complete the experimental programs). At Grade 6, Time was related to IQ only to the extent $r = -.14$, while at Grade 12 this relationship was $r = -.61$. Similar inter-grade differences appear in this column for the coefficients between Time and: reading speed, error rates during preliminary programs, and achievement rates on

Table 27

Intercorrelations among Ability, Preliminary Program, and Experimental Program Variables for Grades 6 and 12

| | Ability Variables | | | | | | Preliminary Program Performance Variables | | | | | | Experimental Program Performance Variables | | | | | | | | | | Mean | | S.D. | | N | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IQ | | $RS_c$ | | $RS_u$ | | WORK RATE | | ERROR RATE | | TOTAL POSTTEST | | PRETEST | | TIME | | ERRORS | | POSTTEST | | RETENTION | | | | | | | |
| Grade Level | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 |
| IQ | - | - | .68 | .57 | .51 | .57 | -.38 | -.62 | -.44 | -.61 | .72 | .74 | .51 | .36 | -.14 | -.61 | -.64 | -.54 | .70 | .69 | .64 | .61 | 107 | 109 | 13 | 13 | 304 | 289 |
| Corrected Reading Speed | | | - | - | .82 | .99 | -.38 | -.56 | -.39 | -.43 | .60 | .48 | .43 | .23 | -.21 | -.47 | -.53 | -.39 | .64 | .42 | .51 | .34 | 18 | 37 | 7 | 10 | 288 | 294 |
| Uncorrected Reading Speed | | | | | - | - | -.40 | -.57 | -.25 | -.43 | .46 | .48 | .34 | .23 | -.22 | -.47 | -.38 | -.39 | .51 | .42 | .47 | .34 | 18 | 37 | 7 | 10 | 288 | 254 |
| Characteristic Work Rate | | | | | | | - | - | .04 | .40 | -.28 | -.56 | -.27 | -.33 | .63 | .64 | .18 | .42 | -.30 | -.48 | -.25 | -.39 | 140 | 98 | 26 | 19 | 259 | 297 |
| Error Rate on Preliminary Programs | | | | | | | | | - | - | -.58 | -.70 | -.30 | -.24 | -.07 | -.45 | .58 | .52 | -.47 | -.56 | -.43 | -.42 | 16 | 7 | 12 | 8 | 280 | 269 |
| Total Posttest, Preliminary Programs | | | | | | | | | | | - | - | .54 | .33 | -.07 | -.46 | -.70 | -.61 | .83 | .70 | .72 | .58 | 106 | 169 | 51 | 34 | 283 | 269 |
| Pretest | | | | | | | | | | | | | - | - | -.10 | -.27 | -.47 | -.19 | .51 | .24 | .57 | .27 | 8 | 10 | 7 | 8 | 291 | 294 |
| Time | | | | | | | | | | | | | | | - | - | -.19 | -.13 | -.03 | -.38 | .04 | -.31 | 140 | 87 | 33 | 22 | 140 | 164 |
| Error Rate | | | | | | | | | | | | | | | | | - | - | -.73 | -.75 | -.65 | -.67 | 33 | 21 | 19 | 11 | 287 | 219 |
| Posttest | | | | | | | | | | | | | | | | | | | - | - | .79 | .73 | 52 | 74 | 27 | 19 | 288 | 219 |
| Retention | | | | | | | | | | | | | | | | | | | | | - | - | 27 | 56 | 20 | 22 | 279 | 219 |

preliminary programs. The exception is the similar, high degree of correlation between work rates on preliminary and experimental programs (.63 and .64) which were present at both grades.

One final observation of interest from Table 27 is the correlation between corrected and uncorrected reading-speed scores. The extent to which this correlation fails to be perfect (1.00) reflects the extent of hasty and careless performance during the Tinker Speed of Reading Test. This test requires S to read a two-sentence item and cross out the single word which does not belong in that context. Designed to be a pure "speed test," its items are written so as to insure an extremely high probability of correct responding on each item. Simply stated, every item is very easy; the key word is obviously incorrect. Because of this, little "power" component remains, and the test measures reading speed, not comprehension. Therefore, errors committed during this test can be attributed to carelessness and haste, not to lack of ability to comprehend. The correlation coefficient between corrected (number of items attempted minus number of errors) and uncorrected reading speed for twelfth graders was .99; for sixth graders it was only .82. The difference between them (assessed by Z transformation; Guilford, 1956) is highly significant ($P < .01$). It provides further evidence that careful reading and work habits are more predominant among twelfth than among sixth graders.

Consideration of the correlational data obtained at the two grade levels leads to two clear conclusions. The first is that self-adopted work rate is a highly stable characteristic of individuals at both grade levels. The second is that, while the working speed which sixth graders adopt is not strongly related to ability measures, the speed at which twelfth graders work coincides rather closely with their abilities to read and learn.

# DISCUSSION

The goal of programmed instruction is to provide an opportunity for individualized learning. Learning may be considered to be individualized when each student, with his own unique combination of knowledge, skills, and abilities, is enabled to pursue a learning track which is best suited to shaping his particular entering behaviors into explicit criterion or exitting behaviors. Programmed instruction can, to a much greater degree than conventional instruction, provide a learning experience for each student which is unique to him as an individual. It may be unique in terms of the kind of stimuli which are encountered, as is the case during branching or multiple-track programs, or in terms of the rate at which the stimuli are encountered, as is the case during linear programs, administered under student-adopted pacing conditions.

The purpose of this study was to consider the efficacy of the second of the the two individualizing strategies, that of permitting the student to progress through a linear program at a pace which he adopts. To be effective, this strategy requires that a student can, in fact, adopt a work rate which is adaptive, that is, a work rate which is a function of his unique ability-determined needs and pace which results in optimal learning. Learning may be considered optimal when maximum achievement is reached in minimum time.

The efficacy of administering programs under self-adopted pacing conditions was evaluated in the present study in several ways. The first was by considering the determinants of self-adopted work rate, the extent to which work rate is stable, the extent to which it is related to ability, and the extent to which it may be modified. The second concerned the consequences on performance effectiveness and efficiency of either fast or slow work rates. Attention here was directed toward students who adopt fast work rates even though they commit large numbers of errors and fail to achieve high criterion-test scores, and to those students who adopt slow work rates while committing few errors and achieving high criterion-test scores. Self-adopted work rate is judged to be non-adaptive for the former students, since it appears to be too fast to permit them to learn effectively, and non-adaptive for the latter, since they appear to be working slower than is necessary, hence inefficiently.

Finally, an evaluation was made of the possibility of improving the learning of both types of non-adaptive self pacers by controlling their pace externally. This fixed-paced strategy was designed to force the fast-working, low-achievers to work more slowly, and the slow-working, high-achievers to work more rapidly. All three considerations, the antecedents of work rate, its consequences, and the remedial efficacy of fixed-paced instruction, were investigated at both Grades 6 and 12 so as to determine the extent to which students at different academic levels differ in their ability to adopt a work rate that optimizes learning.

## The Antecedents of Self-Adopted Work Rates

A major assumption underlying the strategy of self-paced administration of programs is that the rate at which a student works accurately reflects the amount of time which is necessary for him to respond correctly. It is expected, therefore, that during work on a program with a given rate of lesson development, less capable students will adopt slower work rates than more capable students. If a strong inverse relationship is found between ability and time to complete the program, this could be taken as evidence that the self-pacing strategy *is* providing optimal learning. Able students are using their time efficiently, while less able students are spending the extra time they require.

*Work rate and ability* - As discussed earlier, previous studies all agree that program completion time is inversely related to ability variables, but disagree as to the magnitude of this relationship. It was hypothesized that the degree of this relationship may vary as a function of grade level: the work rates of younger students may be less related to ability than is the case for older students.

The results of the present study tend to confirm that hypothesis. While work rate, as measured by program completion time, was found to be inversely related to ability at both Grades 6 and 12, the magnitudes of the observed relationships were rather different at the two grades. At Grade 6, the correlations between work rate and IQ were: -.38 for preliminary programs, and -.14 for the Electrical Circuits Program. At Grade 12, the correlations between work rate and IQ were: -.62 for preliminary programs, and -.61 for the Relativity Program. These findings are consistent with the hypothesis that self-adopted work rate is more closely related to ability among older student groups.

A recent study by Gagné and Gropper (1965) includes correlation coefficients between IQ and program completion time among eighth graders. The average of six reported coefficients (three separate groups on two separate programs) was calculated (by Z transformation) to be -.43. This compares closely to the average r = -.38 observed for eighth graders by Kress and Gropper (1964a) and -.14 to -.38 observed for sixth graders in the present study.

Another recent source of evidence bearing on the relation between intelligence and work rate was presented by Klaus (1964), who reports significant differences in time to complete a program and also time-per-frame measures as a function of IQ level: the higher-IQ Ss adopted faster work rates on two programs of varying step sizes. His sample was composed of 192 male, high-school students over 16 years of age The Klaus finding is consistent with the significant effect of Ability on time to complete the Relativity Program observed in the Grade 12 Experiment of the present study. At Grade 6, on the other hand, the difference in time to complete the Electrical Circuits Program between high and low ability Ss was not significant.

The available evidence on this issue is by now substantial and points, fairly consistently, to the conclusion that self-adopted work rates become more a function of ability at the higher grade levels. It remains a question, however, whether this change occurs as a function of changes in student work habits as they progress through grade levels, or whether it simply reflects attrition in the ranks of fast-working, low ability students. It is possible that work habits become modified as students experience success or failure following particular rates of work. Certainly, there is ample time for work habits to be shaped toward more adaptive patterns between the sixth and twelfth grades. On the other hand, it may well be that the low-ability students who exhibit habitual, rapid, non-adaptive working styles in the sixth grade simply fail ever to become twelfth graders. They may, by that time, either have quit school or been placed in special classes. The available evidence does not permit a choice between these two possibilities.

Stability of work rate - The present study adds further support to previous findings that self-adopted work rate is a highly stable characteristic of individuals. Work rate, on two programs, was found to be consistent among both sixth ($r = .78$) and twelfth graders ($r = .72$). This finding was consistent with the Kress and Gropper (1964a) report of stable work rates among eighth graders (average $r = .80$). It appears, therefore, that one of the major determinants of a student's self-adopted work rate is his habitual style of work.

A similar, high degree of stability of response times has been found in a somewhat different context. Kagan, Rosman, Day, Albert, and Phillips (1964) report high intra-individual stability in the tendency to reflect over alternative solutions (as measured by response time) when several response alternatives are simultaneously available. Students (from grades 1-4) were found to be habitually "reflective" (long response latencies) or "impulsive" (short response latencies) during a variety of such tasks. These investigators cite, as possible determinants of the disposition to be a reflective or an impulsive responder, constitutional predispositions, degree of task involvement, and anxiety over task competence. They indicate, further, that these dispositions are orthogonal to verbal skills.

The task of responding to the frames of a program appears to bear some similarity to the tasks employed by Kagan, et al. During a program, the student must choose a response from alternatives which are available either on the page, or in his verbal repertory. It would certainly be of interest, in future research, to determine the relationship between individual work rate during programs and the reflectivity-impulsivity dimension; both are measured by response latencies and both display unusual stability over testing periods and tasks. Moreover, both appear to be important determinants of the quality of performance.

Work rate and administrative setting - Frye (1963) reported that work rates during a program may be affected by student recognition of certain competitive aspects of a group situation. It was observed informally during the Kress and Gropper (1964a) study that students attended to the observable progress of their peers and appeared to adjust their work rates in response to it.

In the present study, programs were administered to students working either in isolation from, or in the presence of, a group of peers. This difference in administrative setting was found to affect self-adopted work rates at both grade levels. In each case, the isolated students adopted faster work rates. It seems clear that the rate at which students choose to work can be modified by situational variables.

The finding that the group setting led to work rates that were slower than resulted from the isolated setting was not consistent with the Kress and Gropper (1964a) observations of group influence on work rates. It was expected that seeing peers work fast in the group setting would tend to speed up the slower students and produce faster work rates than would be found in the isolated setting. Contrary to expectations, the presence of peers apparently led to slower work rates than were noted among the isolated students. A certain amount of anxiety was manifested by isolated Ss, particularly during the Grade 6 Experiment, concerning the whereabouts of friends with whom they had arrived. There appeared to be some concern over being "left behind." Considering that the task was rather long and that the environment was unfamilar, it may have been more reassuring than distracting, in this instance, to observe the progress of others. While it is difficult to determine the extent to which this effect is limited to the particular situations employed in these experiments, as compared with in-school situations, it does appear that situational factors can affect self-adopted work rates.

The observed stability of work rate at Grades 6 and 12 indicates that both groups of students possess working styles which are consistent even though they are subject to modification by situational variables. However, the rates at which younger students habitually work on a program are only modestly related to ability variables. Habitual work rates of older students, on the other hand, are rather highly related to their ability. The determinants of work rate thus appear to be different for students of different grade levels.

The first assumption of the self-pacing strategy appears to be better justified at higher than at lower grade levels. The work rate adopted by a twelfth-grade student is much more likely to be a function of his unique abilities than that adopted by a sixth-grade student. That is, the twelfth-grader's rate is more likely to reflect the amount of time which is necessary for him to respond correctly. The consequences of this situation are considered in the following section.

## Consequences of Self-Adopted Work Rates

From the foregoing, it appears that self-adopted work rate during programmed instruction has different correlates at different grade levels. This finding, by itself, does not provide an evaluation of the self-pacing strategy at the two levels. To do so, we must consider the consequences of self-adopted work rates. Does self pacing permit students to learn effectively and efficiently?

An answer to this question was sought in the present study by observation of the relative proportions of students whose self-adopted work rate and achievement patterns deviated from effective or efficient learning patterns. For example, a relatively fast work rate accompanied by relatively low achievement was taken as evidence that the self-pacing behavior of a student is not consistent with learning effectiveness. A relatively slow work rate accompanied by relatively high achievement was taken to be inconsistent with learning efficiency. The greater the number of students who display either of these patterns, the less promising does an instructional strategy calling for self pacing appear.

Kress and Gropper (1964a) observed that the self-pacing strategy resulted in non-adaptive patterns of both types, i.e., fast-working, low achievers and slow-working, high achievers, at Grade 8. The work rate and achievement patterns observed in the present study revealed a similar situation at Grade 6. About as many lower achievers adopted fast work rates as adopted slow work rates. Likewise, among higher achievers there were nearly equal numbers of fast and slow workers. Among twelfth graders, on the other hand, non-adaptive patterns were not much in evidence: few low achievers were found among the faster workers, and few high achievers among the slower workers.

The correlation coefficients between time taken to complete the experimental lesson and scores on achievement tests also reflect the difference observed between sixth and twelfth graders. At Grade 6, the correlation coefficient between time and posttest was -.03; between time and retention, .04. Both indicate that variation in self-adopted work rates was unrelated to variations in achievement. At Grade 12, the analogous coefficients were: -.38 (between time and posttest) and -.31 (between time and retention). At Grade 12, the students who adopted faster work rates tended to be higher achievers. These correlational data, of course, verify that non-adaptive patterns of work rate and achievement were less in evidence among the older students.

The assumptions underlying self-paced program administration appear to be much less justified at Grade 6 than they are at Grade 12. Sixth-grade students work on frames at rates which bear little relation to their ability and which, in many instances, preclude optimal learning. Too many low achievers work quickly despite their obvious lack of successful responding. Knowledge that they are incorrect, as provided by check pages, appears ineffective in modifying their hasty approach to each frame. By the same token, many high achievers spend more time than may be necessary considering other students of like ability who achieve as well in less time. An alternative to self pacing would thus seem to be in order for non-adaptive self pacers of both types, particulary at the sixth grade where so many students demonstrate a need for it.

The Remedial Efficacy of Fixed-Paced Instruction

If it is true that some students, particularly younger students, fail to adopt work rates which are consistent with their ability and which appear responsible for less-than-optimal learning then remedial treatment appears necessary for these students. A major purpose of this study was to evaluate the efficacy of one such treatment, that of forcing students to work at an externally-controlled pace which is designed to coincide, more closely than does their habitual self-adopted work rate, with their ability.

Two types of externally-controlled, fixed pacing were evaluated. The first was designed to improve learning effectiveness by forcing fast-working, low achievers to work more slowly. The second was designed to force habitually slow-working, high achievers to work more rapidly without achievement decrement (hence more efficiently).

The strategy of administering programs at a slow, fixed pace - The results of the experiments at both grade levels indicate that programmed learning is not more effective when low-ability students are forced to spend more time on each frame of the program; this strategy failed at both Grades 6 and 12. The Grade 12 result was not surprising since a forced slowdown was not really indicated for twelfth graders. Their self-adopted work rate and achievement patterns were such that failure to achieve among these students could not very well be attributed to failure to spend adequate time on the program; low achievers tended to be slow workers.

The failure of the strategy at Grade 6, however, cannot be attributed to an absence of candidates for remedial treatment. Many sixth graders persistently adopted fast work rates despite high numbers of committed errors and subsequent low scores on achievement tests. If a forced slow pace were to benefit fast-working, low achievers, the benefit would likely arise from the extra reading time prior to construction of responses and, perhaps, from extra rehearsal of correct responses. Reports from the sixth-grade monitors describe a different pattern of behavior during the slow, fixed-paced sessions. Students in this condition apparently tended to respond quickly, well before the fixed interval had elapsed, and then simply waited until instructed to turn the page. While such a reaction might be expected early in the program, one might also expect that the student would gradually expand his working time to more nearly fill the fixed interval allotted to each frame. However, these students persisted in their rapid response patterns. These reports imply that a substantial portion of the allocated time was simply not spent in task-related behavior.

This outcome was different from an experiment reported by Kress and Gropper (1964b) in which the administration of a program at a slow, fixed-pace led to fewer errors and higher achievement than resulted from self-paced administration. However, their observations were restricted to students (eighth graders) who, on previous self-paced programs, had demonstrated themselves to be relatively high achievers. So that, while the observed superiority of fixed pacing was unexpected, Kress and Gropper suggested that even larger gains might be possible among students who achieve poorly from self-paced programs. There was, of course, more room for improvement and, perhaps, better reason to expect it among the slowed sixth graders of the present study. The fact that no such improvement occurred implies that more potent techniques for slowing them down are necessary.

It seems clear that greater control must be exerted over the attending behavior of fast-working, low achievers. Strategies are needed which either modify the habitual working styles of such students or which modify the behavior of these students during a program upon which progressing to each new frame is made contingent. The most direct solution for the successful administration of programmed instruction would appear to be found in the latter. When a student commits an error he could be required to do something more than glance at the check page before going to the next frame. As suggested in an earlier paper (Kress and Gropper, 1964a), this might range from simply requiring the student to acknowledge with an X on the confirmation page that his answer was incorrect, to requiring that the frame be repeated until he responds correctly. Whatever the requirement may be, the modification of careless working behavior calls for more than the simple provision of extra time during which the student may or may not spend the extra time appropriately.

The strategy of administering programs at a fast, fixed-pace - The strategy of speeding high-ability students so as to optimize their learning efficiency was no more successful at Grade 12 than the slowing strategy; twelfth graders displayed substantial impairment on all performance variables. Such a strategy, at the fixed pace employed (average speedup over self pacing was 26 percent), thus fails to enhance learning efficiency at Grade 12. However, in view of the demonstrated ability of twelfth graders to adopt a pace, for themselves, which is consistent with effective and efficient learning, the failure of this fixed-paced strategy seems of small consequence.

The outcome of the speeding strategy at the sixth grade is less simple to evaluate. The fixed pace employed did not represent a very great speedup over their predicted self-adopted work rates. In fact, for 17 of the 64 students observed, it represented a slower-than-normal pace. Curiously, most of the 17 displayed performance decrement. The 47 who were speeded, on the other hand, finished the program with an average savings in time (compared to self pacing) of 13 percent without significant achievement decrement. The only performance decrement observed for them was in increased error rates during the program. Thus, it appears possible to improve learning efficiency for some sixth graders, but only if the imposed fixed pace is at least as fast as their self-adopted work rates.

The fixed-pacing strategy appears to remedy too-slow work rates among sixth graders while failing to remedy too-fast work rates. The imposition of a rapid pace is, of course, a very different operation from the imposition of a slow pace. The failure of the latter was attributed to its inability to force fast workers to modify their customary behavior. The rapid pace, on the other hand, much more directly forced slow workers to modify their customary behavior. They simply had no opportunity to spend relatively long periods of time on each frame. While numerous alternatives appear better suited to foster more deliberate work habits among careless workers, it is difficult to specify a more direct method to heighten efficiency among deliberate workers.

A word of caution is in order regarding the forced speedup strategy. Since it did lead to the commission of greater numbers of errors during the program, such treatment might be expected to lead to undesirable side effects. However, the interpretation of errors as a measure of performance in fixed-pacing situations is risky since a rapid pace may preclude the construction of responses which could be made but for the shortage of writing time. The dramatic rise in errors may thus be largely an artifact of this particular manipulation which may not indicate failure to form a correct response so much as lack of time to write it out. Moreover, the allocation of more time to overt responses rather than to complete, covert responses may result in a larger number of completed blanks but less learning, and therefore, be a poor strategy. Ultimate judgements about forced speeding strategies should be based upon observations of its effects on long-term retention, transfer, student attitudes, and on subsequent self-adopted work rates.

It should be pointed out that this study provides only a limited assessment of the remedial value of externally-controlled pacing. The complet times chosen for the fixed paces, the tempos employed for frame presen[illegible] were arbitrary. They were limited to two tempo levels: one designed [illegible] down most low-ability students, the other to speed up most high-ability students. While the slowing strategy seemed clearly ineffective, the speeding strategy appears to have some merit. Sixth graders did withstand an average speedup of 13 percent without marked achievement decrement. Although twelfth graders did not withstand the speedup which, for them, turned out to average 26 percent, it is perfectly possible that they might have absorbed a less severe speedup without achievement decrement.

A final point which should be borne in mind concerns the programs which were employed to assess the effects of pacing. Both the Electrical Circuits Program (Grade 6) and the Relativity Program (Grade 12) underwent a series of student tryouts and subsequent revisions prior to their use in the experiment. On the basis of tryout data both were judged to be reasonably effective. However, the experimental samples displayed error rate and achievement scores which were more variable than was expected to arise from self-paced administration. Moreover, achievement was IQ-related on both programs. Conclusions from the present study are, of course, limited to materials of the general type employed here.

## Conclusions

The results of the present study together with those of previous studies cited suggest several conclusions with respect to the efficacy of instructional strategies calling for student-adopted and externally-controlled pacing.

The assumption that self-adopted work rate coincides with student ability appears to be well founded among upper-classmen in high school and among college students. Consequently, self-paced program administration appears to optimize both learning effectiveness and efficiency among these students. For them, self-pacing seems clearly preferable to the fixed-paced strategies employed in this study.

Among younger students, specifically sixth and eighth graders, self-adopted work rates neither coincide well with ability nor do they lead to learning which can be described as optimally effective or optimally efficient. Substantial numbers of these students demonstrate a need for remedial treatment by their non-adaptive work rates. High achievers at Grade 6 can, in some instances, be forced to learn more efficiently by simply forcing them to encounter the frames more rapidly through a controlled pace of program administration. On the other hand, low achievers at Grade 6 do not learn more effectively when forced to spend more time with the program by the imposition of a slow, fixed pace. This does not, of course, indicate that they should be permitted to adopt their own pace. It indicates, simply, that the particular strategy assessed in this study, providing additional time during each frame, is not an effective remedy for their problem.

The maladaptive patterns of work habits observed in this study may very well be characteristic of students who have been described in other contexts as "under-achievers." Both students who learn less and students who learn more slowly than would be predicted on the basis of their ability are displaying under-achievement.

The fast-working, low achievers observed at Grade 6 displayed an habitual approach to programmed learning which appears to be related to what Kagan, et al (1964) have called "impulsivity." The prevalence of such a working style among younger students and its stability over time and across tasks suggest it is a performance dimension which may have detectable effects in many different tasks.

It would be of interest in future research efforts to study the generality of inappropriate self-study styles to tasks other than instructional programs. Further, it would be of interest to determine the stability of such styles over longer periods than are covered by existing studies. This determination would reveal whether such students gradually develop more appropriate habits by the time they reach the higher grades or whether they drop about before ever reaching them. Finally, if under-achievement can be traced to an orderly performance dimension, the development of remedial strategies which foster more successful self-study habits would be both feasible and potentially rewarding.

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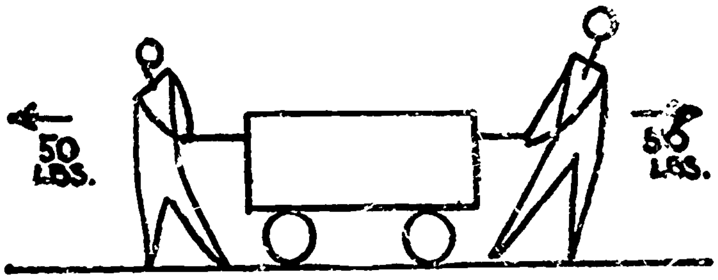
## APPENDIX A

### Criterion Tests and Sample Frames from Each Program

## FORCE & MOTION PROGRAM
(sample frames)

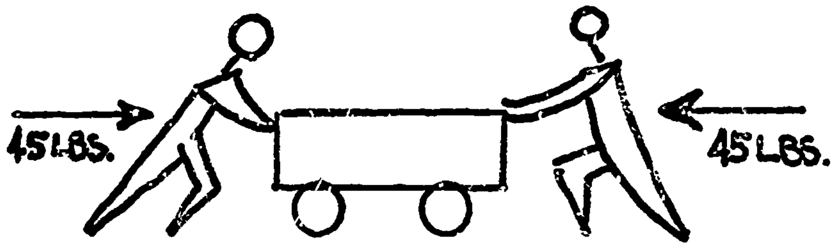
44.

These two men are pulling against each other with the same amount of force. What will happen to the wagon? IT WILL STAY WHERE IT IS. (REMAIN AT REST) WON'T START TO MOVE.



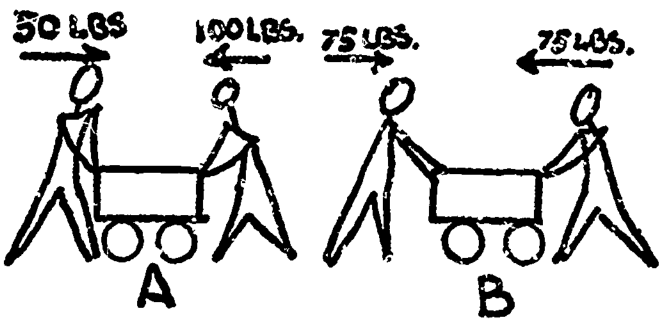

45.

These two men are pushing against each other. What will happen to the wagon? IT WILL REMAIN AT REST. (IT WON'T MOVE.)



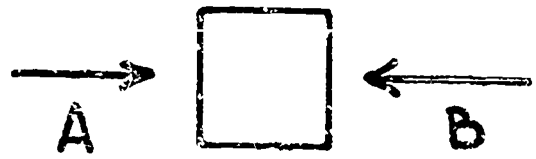

46.

The wagon which will remain at rest is wagon B. Wagon A will start to move.



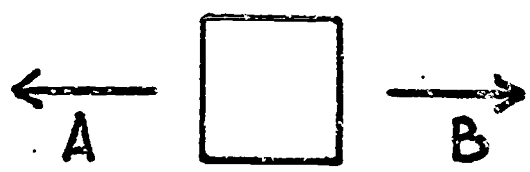

47.

Forces A and B both act toward the box. But since force A acts to the right and force B acts to the left, we say that they act in OPPOSITE directions.



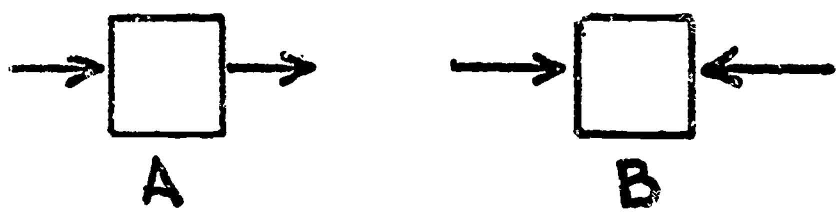

48.

Both forces act away from the box, A to the left, B to the right. Forces A and B act in OPPOSITE directions.



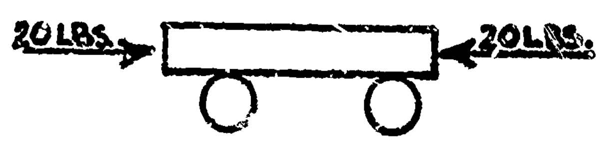

49.

The forces acting in opposite directions are shown in B. The forces acting in the same direction are shown in A.




50.

This wagon will remain at rest because the two forces are EQUAL in strength and act in OPPOSITE DIRECTIONS.

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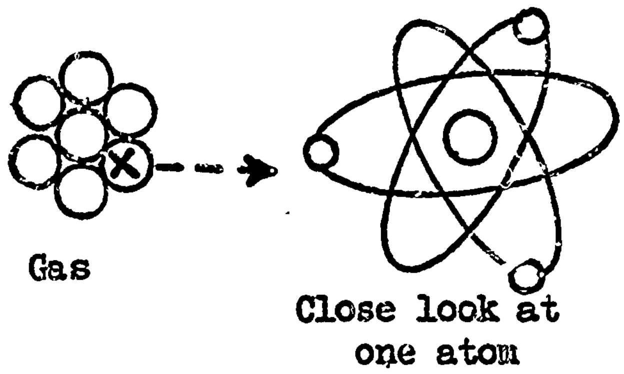
*Subjects were required to make constructed responses for all frames. The sample frames reproduced here are those which were presented to them as confirmation frames after they had made their own responses. The correct constructed responses appear in capital letters.

ATOMIC STRUCTURE PROGRAM
(sample frames)

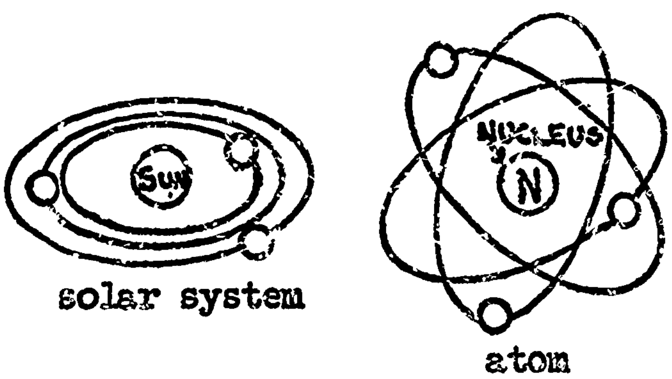
51.

If we took a closer look at one atom of this gas, we would see that it has MORE THAN ONE part.



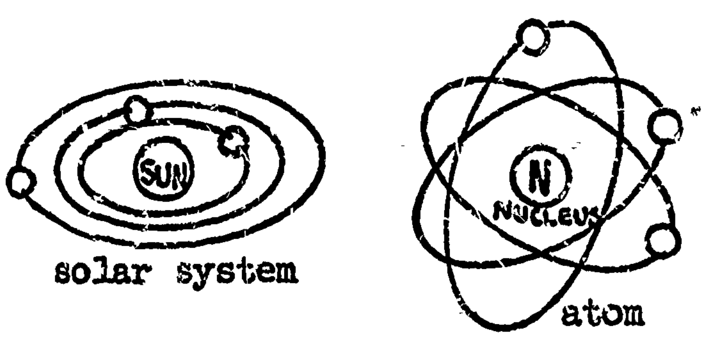

52.

Atoms look something like the solar system. Just as the center of the solar system is the sun, the center of an atom is the NUCLEUS.



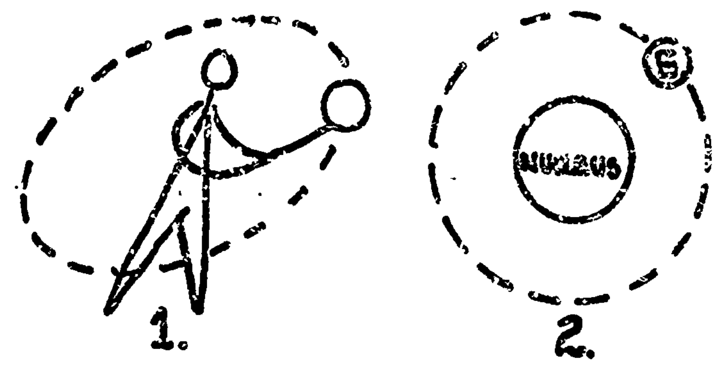

53.

Planets move in paths, called orbits, around the sun. In this atom, we can see some particles moving in PATHS (ORBITS) around the NUCLEUS.



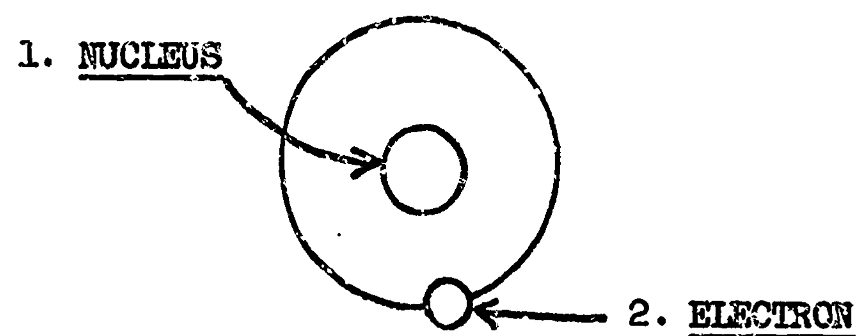

54.

The boy in #1 is spinning a stone at the end of a string. The stone moves in a path or ORBIT around the boy. Similarly, the part labelled (E) in #2 moves IN AN ORBIT AROUND THE NUCLEUS.



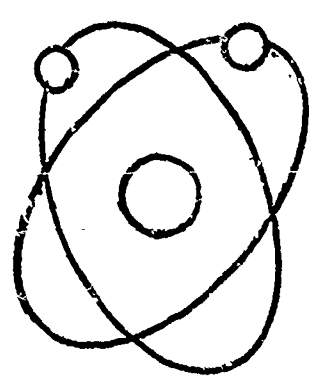

55.

The small part orbiting around the nucleus is called an electron. Label the two parts of the atom.




56.

This atom has two ELECTRONS. Describe how they move. THEY (BOTH) MOVE IN PATHS (OR ORBITS) AROUND THE NUCLEUS.



25.

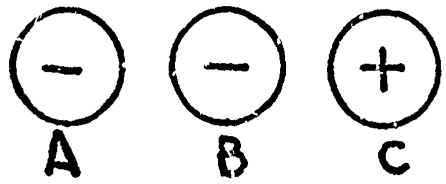
Charged particles act like the poles of a magnet. Two different (unlike) poles attract, or pull toward, each other. Similarly, two differently charged (unlike) particles will ATTRACT each other.


26.

Two same (like) poles of a magnet repel, or push away from, each other. In the same way, two particles with the same (like) charges REPEL each other.


27.

An electron is repelled by another negative charge, but is attracted by a positive charge. Particle B will move toward particle C and away from particle A.




28.

Because they are alike, these two negative charges will move APART,

and these two positive charges will move APART.

29.

Two negative charges will move AWAY FROM each other, but a negative charge and a positive charge will move TOWARD each other.

30.

Write Attract beside the charged particles that will move together. Write Repel beside the charged particles that will move apart.

1. ⊕ ⊖ ATTRACT
2. ⊕ ⊕ REPEL
3. ⊖ ⊖ REPEL
4. ⊖ ⊕ ATTRACT

31.

This charged particle ⊖ will be attracted by A POSITIVE CHARGE and repelled by A NEGATIVE CHARGE (ELECTRON).

32.

Draw two charged particles which move away from each other.

⊕ ⊕

OR

⊖ ⊖

Draw two charged particles which move toward each other.

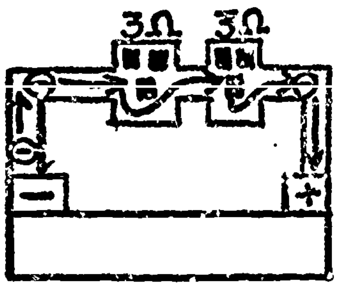
⊕ ⊖

OR

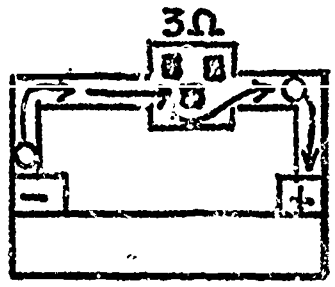
⊖ ⊕

178.

Adding resistance in series, adds to the number of collisions the electrons have with obstacles. The circuit with more opposition to electrons is circuit A.




A



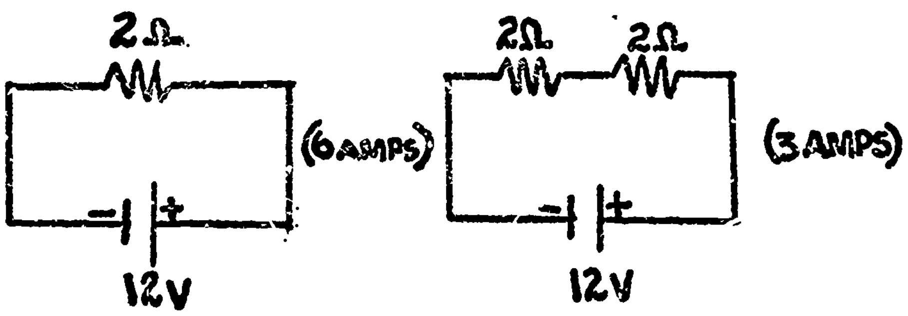

B

179.

When resistance is added to a series circuit, current flow DECREASES because the electrons have MORE collisions with obstacles.

180.

Each time we add a new resistance in a series circuit, the current flow is DECREASED.

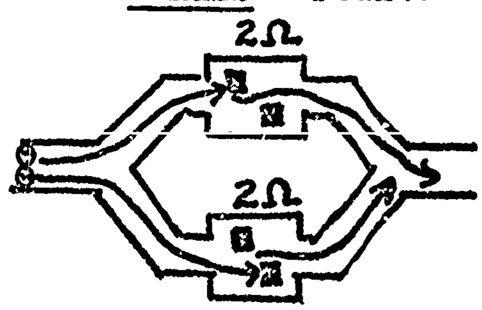



181.

Why is current reduced by the addition of resistances in a series circuit? BECAUSE THE ELECTRONS HAVE MORE OBSTACLES TO COLLIDE WITH (BECAUSE IT ADDS TO THE NUMBER OF THINGS THE ELECTRONS BUMP INTO).

182.

The circuit which provides more separate paths for electrons is the PARALLEL circuit. The one which crowds the electrons into one path is the SERIES circuit.

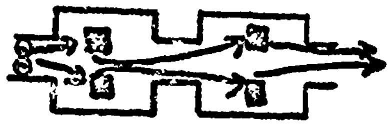


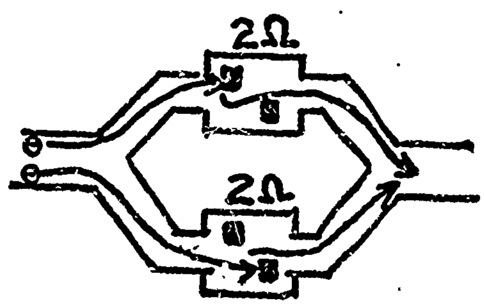

resistances connected in series

resistances connected in parallel

183.

The series connection of a pair of resistances leads to MORE collisions than the parallel connection. Current is reduced more by the SERIES connection.





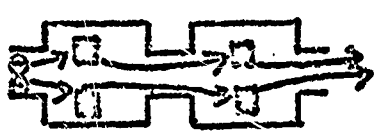

resistances connected in series

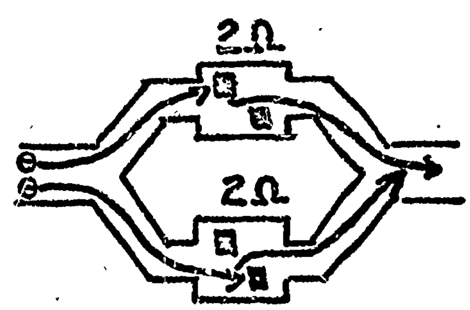
resistances connected in parallel

(Count the Number of Collisions)

184.

Why do fewer collisions occur in the parallel circuit? IT PROVIDES MORE PATHS FOR THE ELECTRONS (ELECTRONS ARE LESS CROWDED).






resistances connected in series

resistances connected in parallel

_________ - test

Name ______________________ Grade ______________

School ______________________ Date ______________

# FORCE

1. Any <u>single</u> force may be one of two basic types. The two types are:

   1. ______________

   2. ______________

2. In order to describe a force fully, two facts are necessary. They are:

   1. ______________

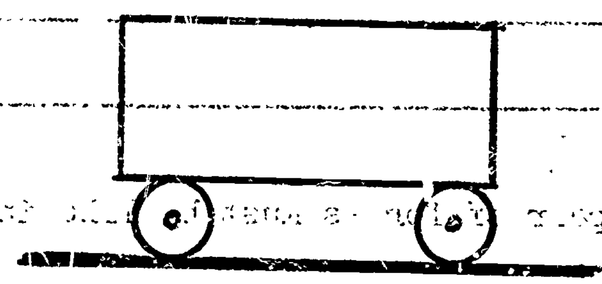
   2. ______________

3. What can we say about gravity when we know that a suitcase weighs 37 lbs.?

______________________________________________

______________________________________________

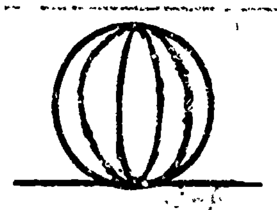
4. Suppose you were asked to apply two (2) separate forces to the car below such that the cart will stay exactly where it is. <u>Neither force may be downward.</u> Diagram (draw in) a pair of such forces in the picture and be sure to <u>label each one fully.</u>



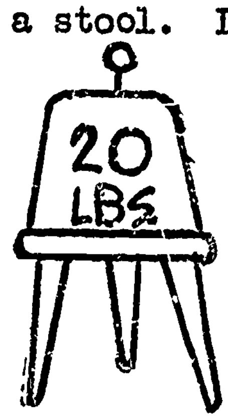
What term could be used to describe the forces? ______________

5. What would happen to this basketball if some balanced forces were applied to it?

______________________________________________



6. This 20-lb. weight is resting on a stool. List each force that is acting and describe each one fully.




______________________________________________

______________________________________________

______________________________________________

______________________________________________

7. What technical term would be used to describe the forces which are acting on:

a parked automobile? ______________

an automobile starting to move? ______________

8. What physical feature (characteristic) of people is determined by the force of gravity?

______________

Explain. ______________________________________

______________________________________________

9. Describe, in words, what a pair of forces must be like in order to be called balanced.

______________________________________________

______________________________________________

10. What effect do unbalanced forces have on resting objects?

______________________________________________

______________________________________________

11. A rock is lying still on a wagon. Indicate whether each of the following is true or false by circling the proper letter.

T F The wagon is pushing up on the rock.

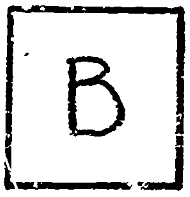
T F The rock is being acted upon by balanced forces.

T F The rock is being acted on by equal and opposite forces.

12. Draw a pair of unbalanced forces acting upon object A.

Draw a pair of balanced forces acting upon object B.

Be sure to label all the forces completely.


13. Explain, in terms of forces, what is meant by the sentence: "An object is held up by the surface of the table."

______________________________

______________________________

______________________________

14. What would you do to find out the strength with which gravity acts on an object?

______________________________.

15. Describe this force fully.

______________________________

______________________________

119 lbs.

________ - test

Name ______________________ Grade ____________

School ______________________ Date ____________

## Atomic Structure of Matter

1. What is the number of different physical states in which matter is found? ________

2. How would a scientist (physicist or chemist) define the term "element?"

______________________________________________

______________________________________________

3.
   A. List each physical state in which elements may be found.

   ______________________________________________

   ______________________________________________

   B. List each physical state in which non-elements may be found.

   ______________________________________________

   ______________________________________________

4. What is the approximate number of different natural atoms? ________

5. What does a scientist (physicist) mean by the term, "matter?"

______________________________________________

______________________________________________

6. What does the atomic number tell us about an element?

______________________________________________

______________________________________________

7. Describe the difference between an element and a non-element.

______________________________________________

______________________________________________

______________________________________________

8. About how many different elements are found in nature? ____________

9. Write a sentence which describes how the make-up of all matter is alike.

______________________________________________

______________________________________________

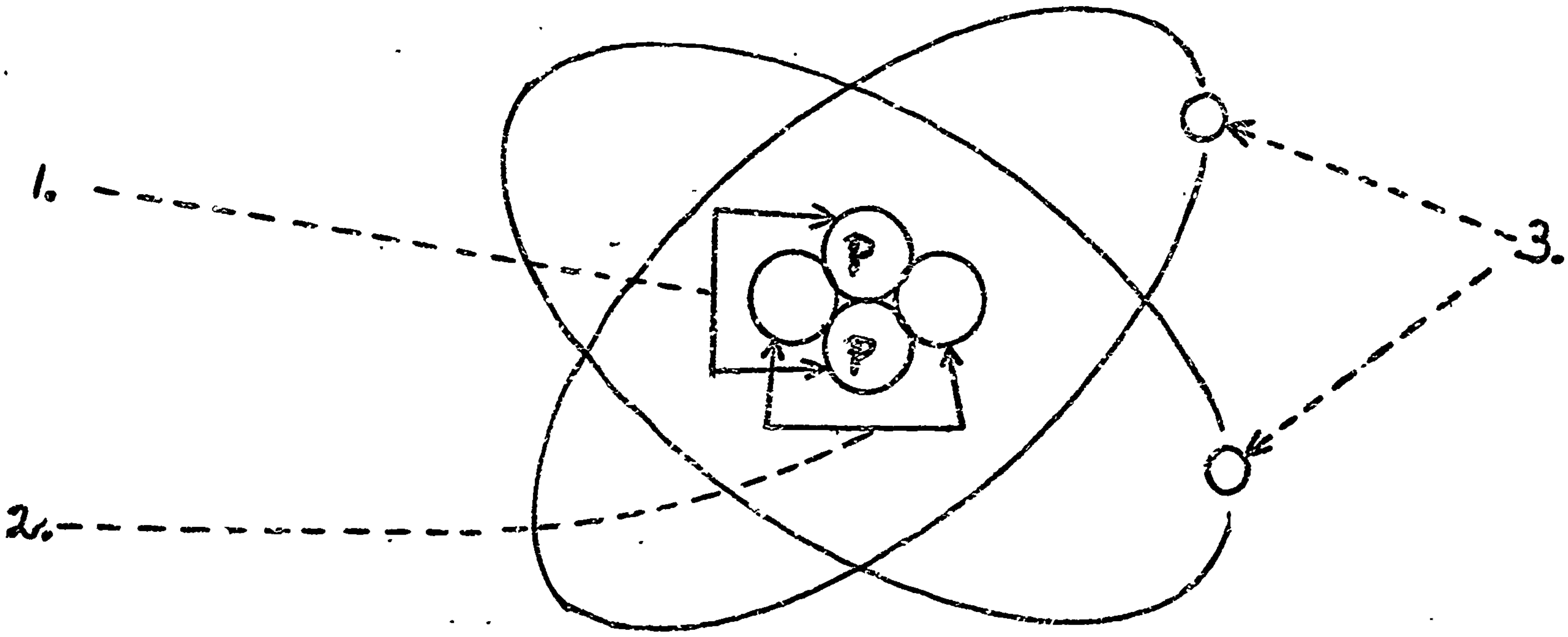
10. Electrons are found in all atoms. In a sentence, describe what electrons do in an atom.

______________________________________________

______________________________________________

______________________________________________

11. Identify each of the numbered parts in the following diagram of the helium atom. Write the correct word on the numbered lines below.




1. ____________________
2. ____________________
3. ____________________

1. and 2., together, form the ____________________.

12. From its atom shown in question 11, what is the atomic number of helium?

____________

13. Below are descriptions of the contents of three atomic nuclei. Write in the atomic number of each one on the line provided.

A. 10 protons
10 neutrons ____________

B. 146 neutrons
92 protons ____________

C. 6 neutrons
5 protons ____________

14. How is it possible to have thousands of different substances on earth when there are so few different kinds of atoms?

________________________________________

________________________________________

________________________________________

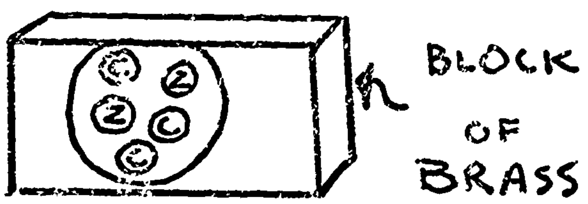
15. The circle inside each of these two substances shows the greatly enlarged view from a very powerful microscope. In what way are the two substances alike?

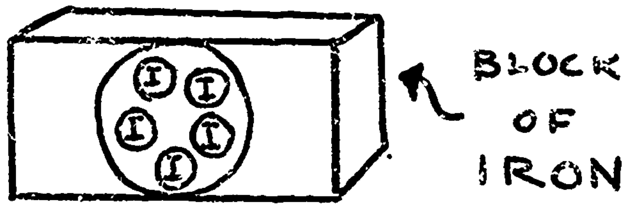
________________________________________

In what way are they different?

________________________________________

________________________________________




16. Without describing the separate parts of the atom, what would you say in answer to the question: What is an atom?

________________________________________

________________________________________

17. Why is the number of natural atoms exactly the same as the number of natural elements?

________________________________________

________________________________________

________ - Test

Name ______________________________ Grade __________

School ______________________________ Date __________

# ELECTRICAL CIRCUITS TEST

## A. Definitions

Briefly define each of the following:

1. Voltage ______________________________________________
______________________________________________
______________________________________________.

2. Electrical resistance ______________________________________________
______________________________________________
______________________________________________.

3. Free electrons ______________________________________________
______________________________________________
______________________________________________.

4. Highly charged objects ______________________________________________
______________________________________________
______________________________________________.

5. An open circuit ______________________________________________
______________________________________________
______________________________________________.

6. A series circuit ______________________________________________
______________________________________________
______________________________________________.

7. A parallel circuit ______________________________________________

______________________________________________________________.

8. An electrical insulator ________________________________________

______________________________________________________________.

9. An electrical conductor ________________________________________

______________________________________________________________.

B. Short Answers

1. Explain the statement: "Voltage and resistance work against each other."

______________________________________________________________

______________________________________________________________

______________________________________________________________

2. List the various effects that charged particles have on each other.

______________________________________________________________

______________________________________________________________

______________________________________________________________

3. What two things are necessary in order to get current flow from a battery?

______________________________________________________________

______________________________________________________________

4. In what direction does current flow from a battery?

______________________________________________

What two forces cause it to flow in that direction?

______________________________________________

______________________________________________

5. What happens to current in a series circuit when:

voltage is increased? ______________________________

resistance is increased? ______________________________

the circuit is broken by the opening of a switch? ______________________________

6. Why do resistances connected in series reduce current flow more than resistances connected in parallel?

______________________________________________

______________________________________________

______________________________________________

7. What must a battery be like in order to create a high voltage?

______________________________________________

______________________________________________

8. Complete this chart. (Fill in the five empty spaces.)

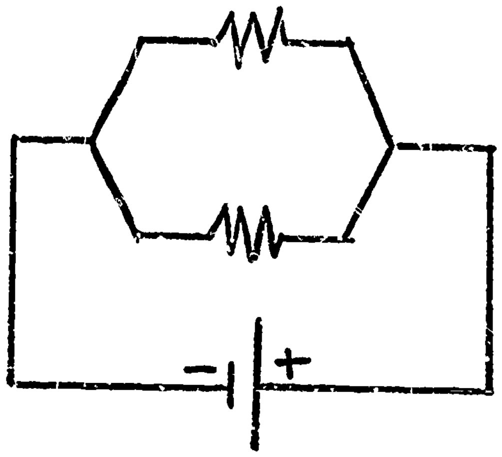
| Quantity | Units in which the quantity is measured | Abbreviation of unit |
|---|---|---|
| Voltage | volts | |
| Current | | |
| | | $\Omega$ |

9. What does an electric current consist of?

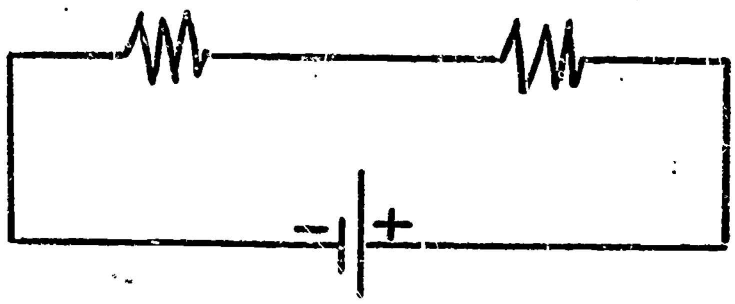
______________________________________________

C. Labelling Circuit Diagrams

1. Label these two circuits.

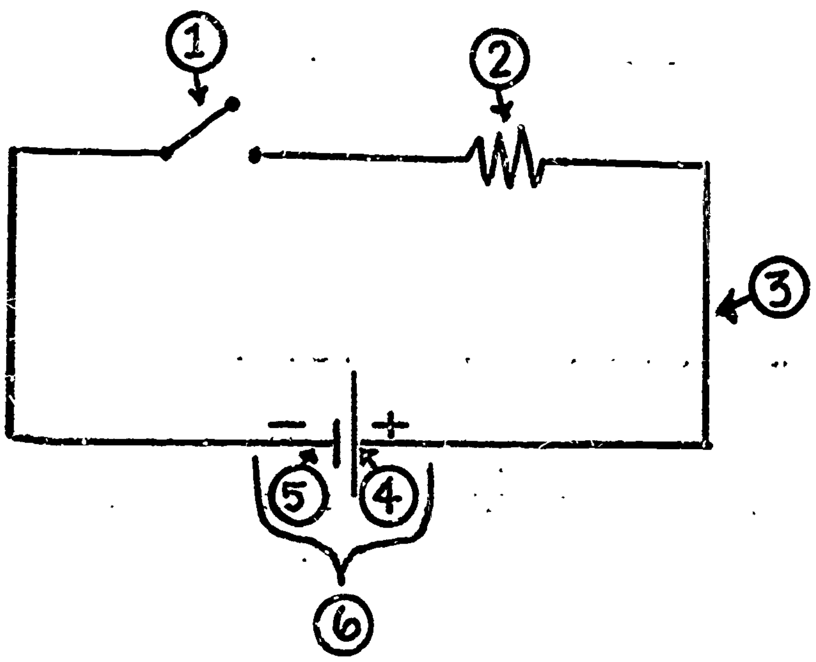



______________________




______________________

2. Label each numbered part of this circuit by writing the correct word in the corresponding blank.

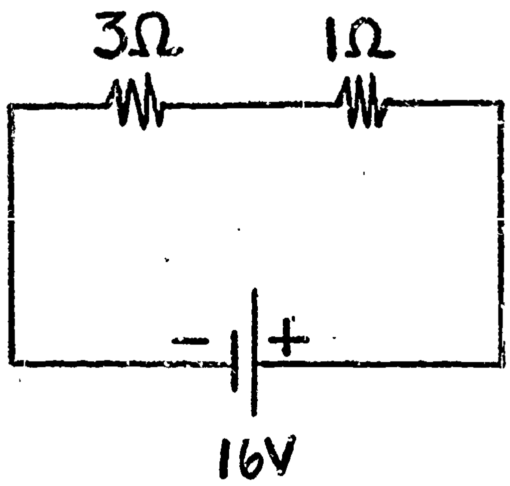



1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________

D. Problems

Write in the correct type for each of these circuits on the blank line and calculate the total current in each. Show all work in the boxes.

1.



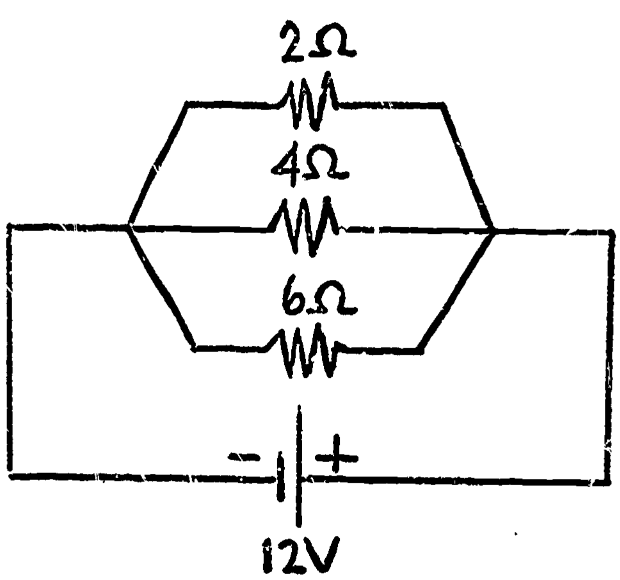

_______________ circuit

**Calculations**

Total Current = _______________

---

2.

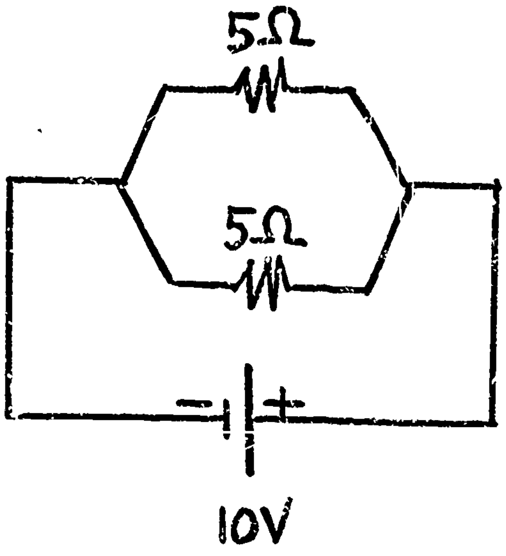



_______________ circuit

**Calculations**

Total Current = _______________

3.



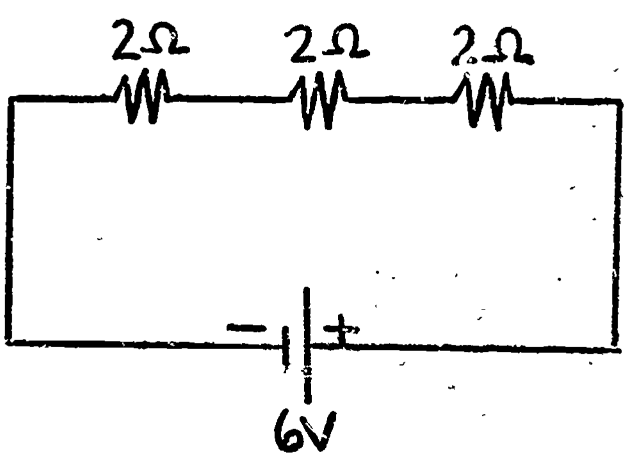

________________ circuit

Calculations

Total Current = ________________

---

4.



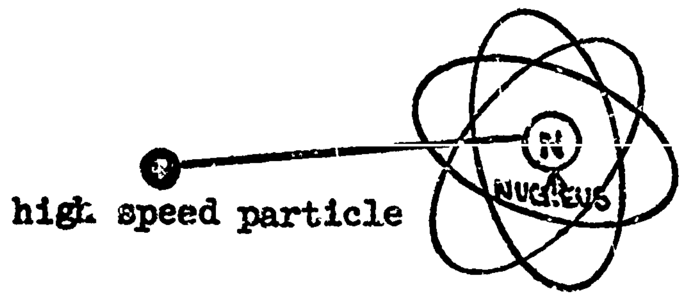

________________ circuit

Calculations

Total Current = ________________

}.

stable atom will become unstable if its
ICLEUS is bombarded by A HIGH SPEED
'AST-MOVING) PARTICLE.



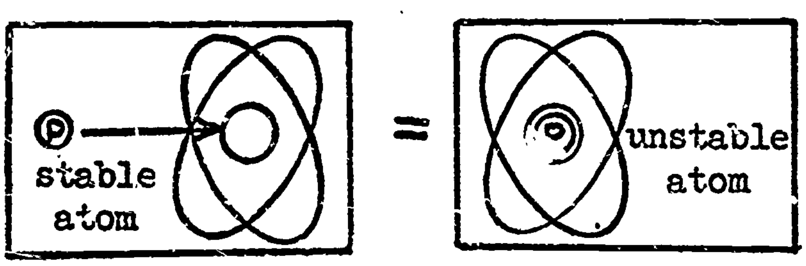

›.

w can a stable atom be made unstable?
HITTING IT'S NUCLEUS WITH A HIGH-
EED PARTICLE.

'.

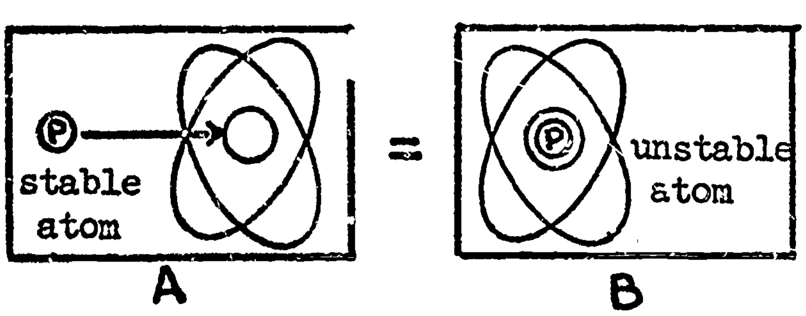
ergy can be converted into mass. When
nucleus absorbs a high-speed particle,
converts the energy of the particle
to more MASS.

less mass than B B. more mass than A




.

en a fast moving proton is taken into
e nucleus, energy is converted into MASS.
us, there would be more mass in part B.




82.

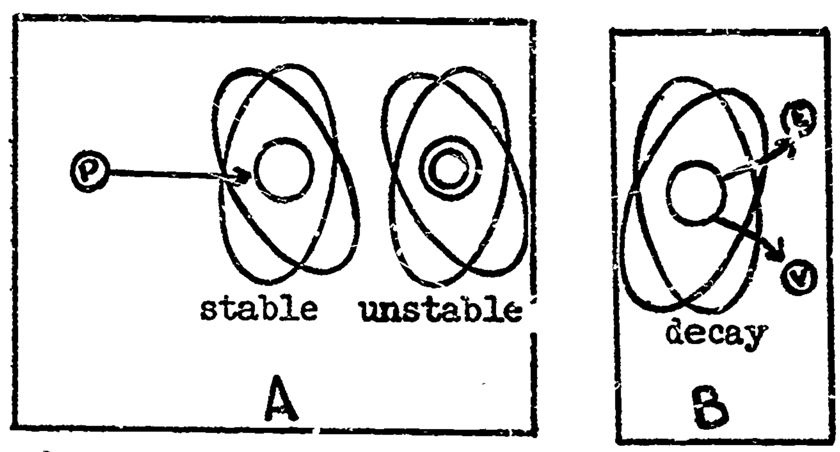
When a high-energy proton is taken into the nucleus of an atom, the atom weighs more than the sum of its original mass and the mass of the proton. This is because some of the proton's energy is CONVERTED INTO MASS.

83.

When a fast moving subatomic particle is taken into a nucleus, mass is gained because SOME OF ITS ENERGY IS CONVERTED TO MASS. But, when a subatomic particle is emitted from a nucleus during radioactive decay, mass is lost because IT IS CONVERTED INTO ENERGY.

84.

The conversion of mass into energy is shown in B. The conversion of energy into mass is shown in A.




85.

In terms of mass and energy describe what happens in the examples.

1. An unstable atom emits subatomic particles. MASS IS CONVERTED TO ENERGY.
2. A stable atom absorbs a subatomic particle into its nucleus. ENERGY IS CONVERTED TO MASS.
3. A subatomic particle and its twin antiparticle come together. MASS IS CONVERTED TO ENERGY.

Subjects were required to make constructed responses for all frames. The sample frames reproduced here are those which were presented to them as confirmation frames after they had made their own responses. The correct constructed responses appear in capital letters.



ERIC

## SUBATOMIC PARTICLES II PROGRAM
(sample frames)

11.

Atomic nuclei are difficult to split apart because their protons and neutrons are held <u>TOGETHER</u> by the <u>STRONG FORCE</u>.

12.

Name the particles in the atom which are affected by the strong force and describe how they are affected. <u>PROTONS AND NEUTRONS ARE HELD TOGETHER IN THE NUCLEUS.</u>

13.

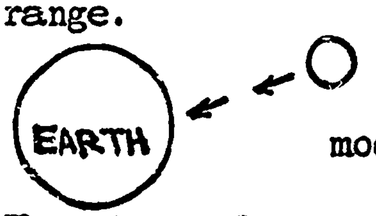
Gravity is the weakest force in nature and the strong force is the <u>STRONGEST</u> force in nature.

14.

The force of gravity acts over millions of miles to hold the moon in a path around the Earth. The moon doesn't go flying into space because it is held by <u>GRAVITY</u>, which is a <u>LONG-RANGE</u> force.

15.

The force of gravity acts over a <u>LONG</u> range.




moon held by gravity

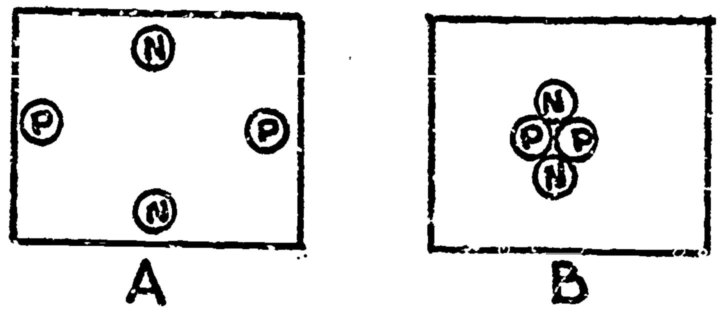
The strong force, which is effective only within the tiny nucleus of an atom, acts over a <u>SHORT</u> range.

16.

Two subatomic particles, one on the moon and one on the Earth, are pulled together (very weakly) by the force of gravity, because it acts over a <u>LONG-RANGE</u>. They are not pulled together by the strong force because it acts over a <u>SHORT-RANGE</u>.

17.

Gravity acts on the particles in A and on the particles in B. But the strong force acts only on the particles in <u>B</u>.




18.

Gravity and the strong force differ in both strength and range. Gravity is a much <u>WEAKER</u> force, but it acts over a <u>LONG(ER) RANGE</u>.

19.

Write GRAVITY or STRONG FORCE beside each description.

| | |
|---|---|
| <u>GRAVITY</u> | The force that acts weakly but over a long-range. |
| <u>STRONG FORCE</u> | The force that holds protons and neutrons in the nucleus of each atom. |
| <u>STRONG FORCE</u> | The force that acts strongly but over a short range. |
| <u>GRAVITY</u> | The force that holds a man-made satellite in orbit around the Earth. |

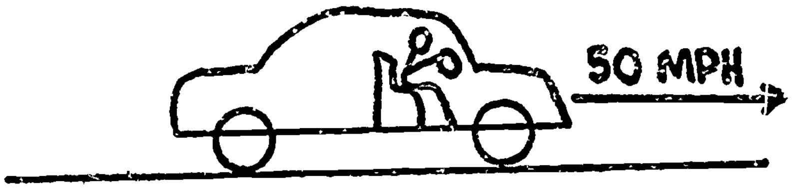
20.

The differences between gravity and the strong force are:

1. <u>GRAVITY IS THE WEAKEST FORCE, STRONG FORCE IS THE STRONGEST.</u>
2. <u>GRAVITY ACTS OVER A LONG RANGE, STRONG FORCE OVER A SHORT RANGE.</u>

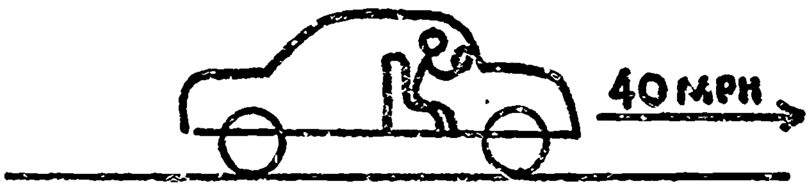
22.

Relative to the ground, the car's speed is 50 mph. The speed of the driver's body, relative to the ground, is also 50 mph.



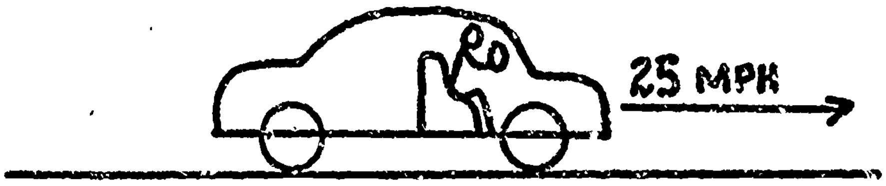

23.

The speed of this driver's body, relative to the road, is 40 mph. Suppose we take the car as the frame of reference. Is the speed of his body the same relative to the car as it is relative to the ground? NO.



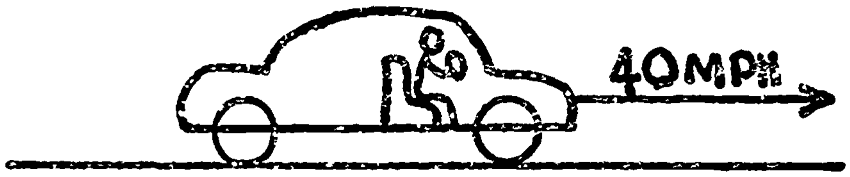

24.

This driver's body is moving at a speed -- relative to the road -- of 25 mph. But, the speed of his body -- relative to the car -- is 0 (ZERO) mph.



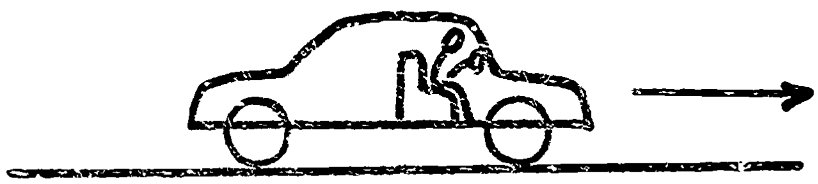

25.

The speed of this man is 0 mph or 40 mph, depending upon the frame of reference used. There are 2 different frames of reference here: (1) the CAR(ROAD), and (2) the ROAD(CAR).




26.

The speed of this man's body is "relative." In other words, it CHANGES from one FRAME OF REFERENCE to another.

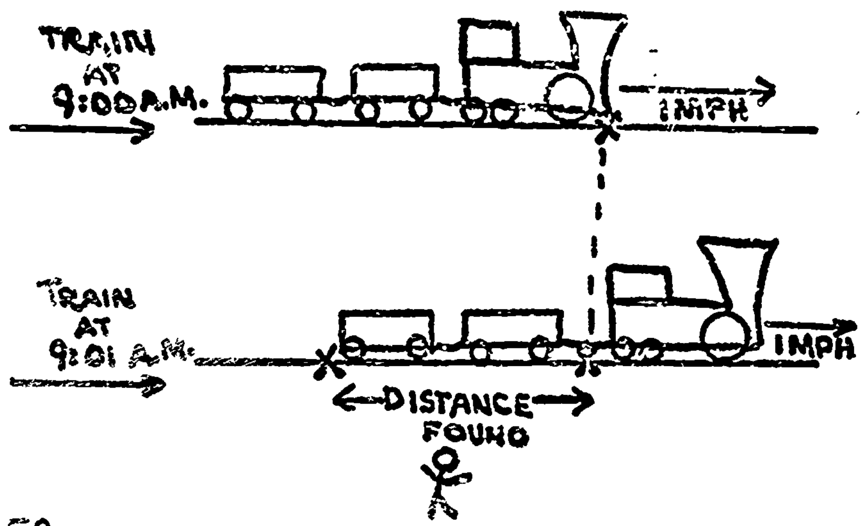


27.

When physicists say that the speed of objects is "relative," they mean that IT VARIES FROM ONE FRAME OF REFERENCE TO ANOTHER.

149.

This man looked at the front of the train, paused one minute, then looked at the back. The distance he found was not the length of the train. His measurement was wrong because he did not observe both ends AT THE SAME TIME (SIMULTANEOUSLY).




150.

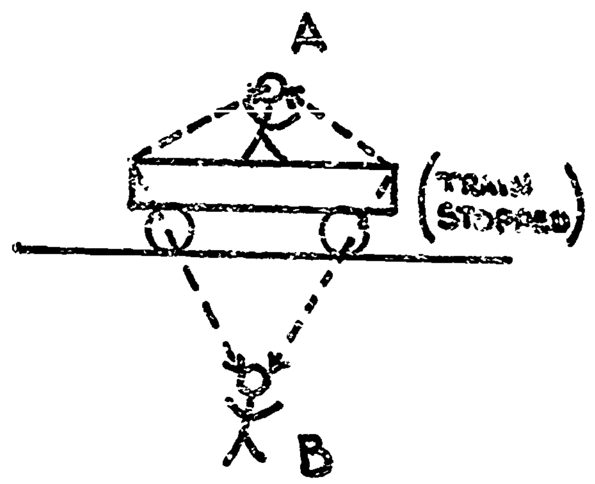
What must an observer do to accurately measure the length of an object? HE MUST OBSERVE BOTH ENDS SIMULTANEOUSLY AND FIND THE DISTANCE BETWEEN THEM.

151.

Because observers in different frames of reference DISAGREE about simultaneity, they will DISAGREE about the length of objects.

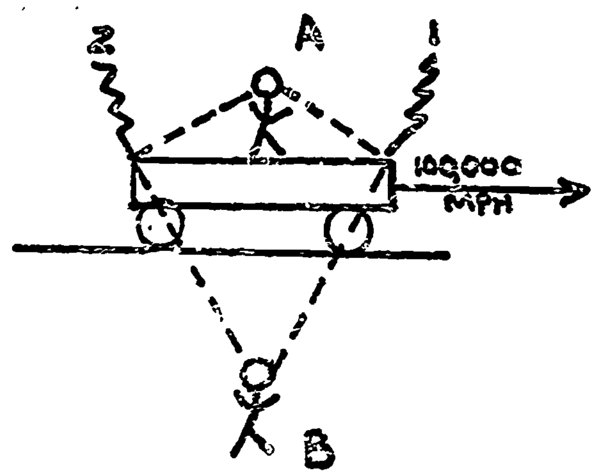
152.

These men will agree perfectly about the length of the train so long as the frame of reference IS THE SAME for both.




153.

Man B measures the train as being shorter than 20 ft. Man A measures exactly 20 ft. Just as the men disagree about the timing of events, they also DISAGREE about the LENGTH of the train.




154.

The reason that observers in different frames of reference disagree about measuring length, or distance, is that they can't agree on SIMULTANEITY. When one observer says the ends were observed simultaneously, the other will say that THEY WERE NOT OBSERVED SIMULTANEOUSLY (THAT ONE END WAS OBSERVED BEFORE (AFTER) THE OTHER).

_________ test

NAME ______________________________ GRADE __________

SCHOOL ______________________________ DATE __________

Elementary Particles I - Test

1. Describe the two states in which subatomic particles may be found.

______________________________

______________________________

2. List the three sources of subatomic particles.

______________________________

______________________________

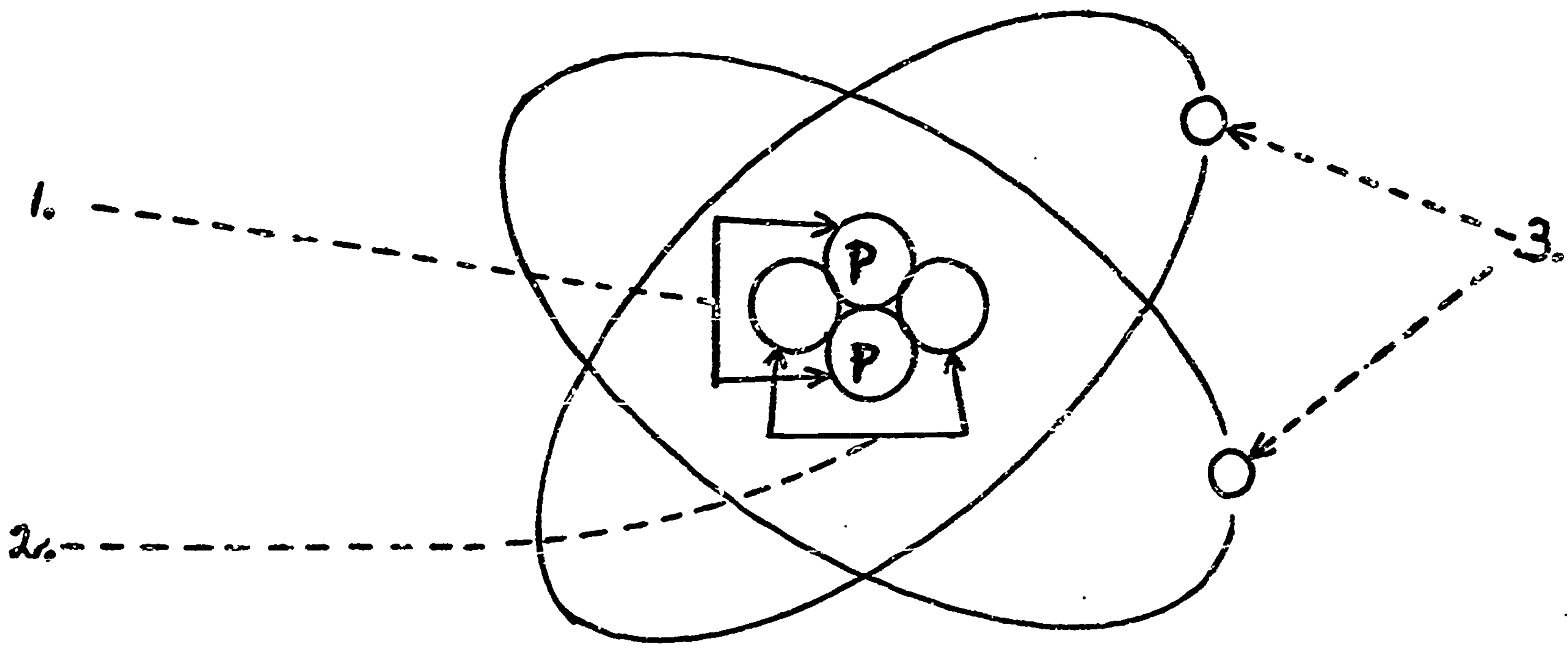
______________________________

3. Explain how physicists can study subatomic particles even though they cannot be seen even with a microscope.

______________________________

______________________________

4. Label the numbered parts of the atom.




1. ______________
2. ______________
3. ______________

1. and 2., together, form the ______________.

5. What is the approximate number of subatomic particles (including anti-particles) which have been found? ________________.

6. Why is it difficult to observe antiparicles here on Earth?

_______________________________________________

_______________________________________________

7. What is meant by radioactive decay? Describe the process.

_______________________________________________

_______________________________________________

_______________________________________________

8. What does the physicist mean by the term "annihilation"? Describe the process.

_______________________________________________

_______________________________________________

_______________________________________________

9. List two examples in which mass is converted to energy.

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

10. Describe <u>one</u> process in which energy is converted to mass.

_______________________________________________

_______________________________________________

11. What is an unstable atom?

12. How can a stable atom be made unstable?

13. Is it possible for a particle to meet an antiparticle without annihilation?

________________.

Explain.

14. Explain the relationship between atoms and subatomic particles.



ERIC

__________ test

NAME ______________________________ GRADE __________

SCHOOL ______________________________ DATE __________

Elementary Particles II - Test

Part I

1. List the four natural forces in order of their relative strength. (Number 1 would be the weakest, number 4 strongest.)

1. ____________________ weakest
2. ____________________
3. ____________________
4. ____________________ strongest

2. (A) The two short-range forces are:

____________________

and ____________________.

(B) The two long-range forces are:

____________________

and ____________________.

3. A. Label the charge on each of the following:

1. proton (P) __________
2. neutron (N) __________
3. electron (E) __________
4. a hydrogen atom __________

4. anti-neutron ($\bar{N}$) __________
5. anti-proton ($\bar{P}$) __________
6. anti-electron ($\bar{E}$) __________
7. an uranium atom __________

3. B. Listed below are three elementary particles, thier charges, and their antiparticles. Complete the chart by filling in the charge on each antiparticle.

| | PARTICLE | CHARGE | ANTIPARTICLE | CHARGE |
|---|---|---|---|---|
| 1. | muon M | — | anti-muon $\bar{M}$ | |
| 2. | neutrino V | 0 | anti-neutrino $\bar{V}$ | |
| 3. | pion Pi | + | anti-pion $\bar{Pi}$ | |

4. Besides having a different strength and range, how else is the electromagnetic force different from the strong force and the force of gravity?

____________________________________________________

____________________________________________________

____________________________________________________.

______________ test

NAME ____________________________________________ GRADE __________

SCHOOL ____________________________________________ DATE __________

Elementary Particles II - Test

Part II

1. What are the two rules which describe the charge-state of anti-particles?

A. ____________________________________________

____________________________________________

B. ____________________________________________

____________________________________________

2. Give one example of an effect which is caused by each of these forces. (an example of something that each force does)

A. Electromagnetic force - __________________________

____________________________________________

____________________________________________

B. Strong force - __________________________________

____________________________________________

C. Weak force - ___________________________________

____________________________________________

D. Gravity - _____________________________________

____________________________________________

3. Summarize briefly the attracting and repelling effects that charged particles have on each other.

________________________________________________

________________________________________________

_________ Test

Name ______________________________ Date __________

School ______________________________ Grade __________

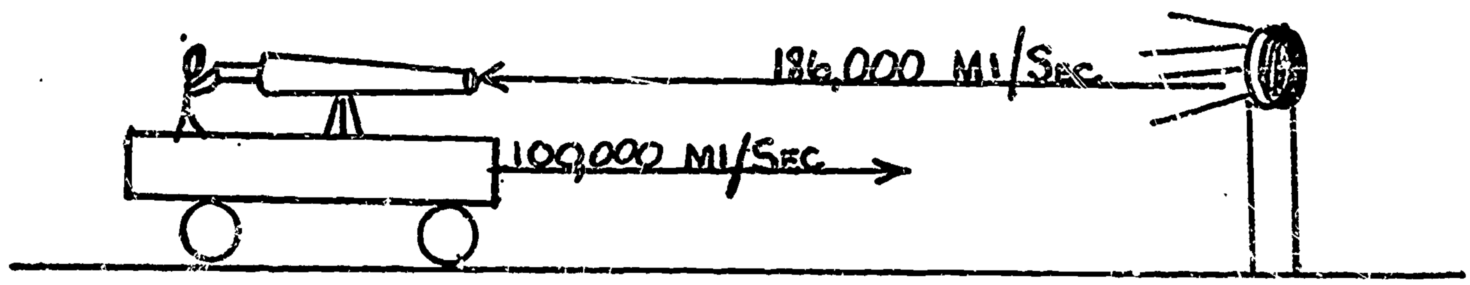
## RELATIVITY TEST

1. This man is traveling toward the light source at 100,000 miles/second. The light is traveling toward him at 186,000 miles/second. The measured speed of the light will be:

   A. According to Classical Physics, __________ miles/second;

   B. According to Relativity Theory, __________ miles/second;

   C. According to actual experiment, __________ miles/second.




2. Explain what is meant by the statement "Time is relative."

______________________________

______________________________

______________________________

3. Why would it be impossible to measure the speed of a ship from inside the ship (with no access to the outside)?

______________________________

______________________________

______________________________

4. What is a "frame of reference"?

______________________________

______________________________

______________________________

5. To what kinds of frames of reference does the Special Theory of Relativity apply?

6. Why is it that the effects predicted by the Theory of Relativity were not noticed much earlier; for example from everyday observation of moving objects?

7. Under what conditions would an observer, located an equal distance between two events, conclude that they were simultaneous?

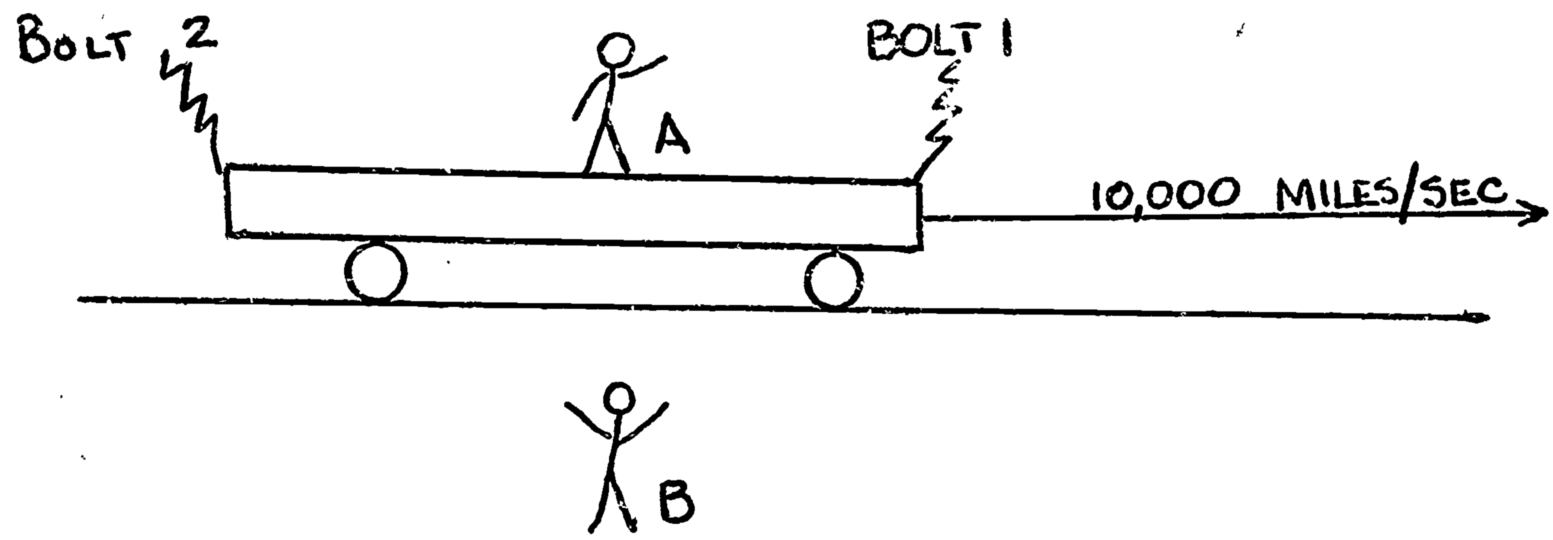
8. (A) Under what conditions will two observers agree on the simultaneity of events, and the length of objects?

(B) Under what conditions will they disagree?

(C) What determines the extent to which they disagree? That is, what must happen for their disagreement to be even greater?

9. Under what conditions do we conclude that two observers are in the same frame of reference with respect to motion?

10. Describe what an observer must do to accurately measure the length of a moving object.

11. 

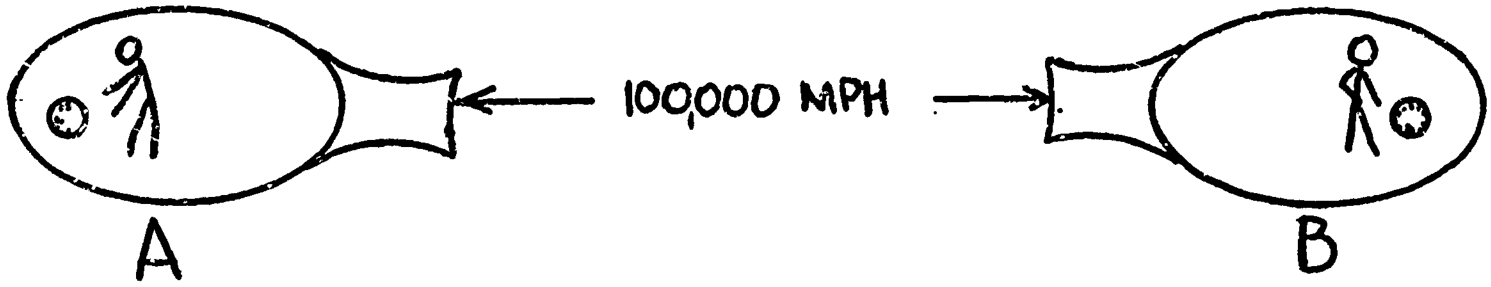

Observer A, standing exactly in the middle of the train, concludes that the bolts of lightning struck simultaneously. Observer B is standing on the ground directly across from A. How would B (on the ground) describe the timing of the bolts?

Would A have come to the same conclusion about the timing of the thunder clap? Explain.

If B had seen them strike simultaneously, how would A (on the train) describe the timing of the bolts?

According to Einstein, which man is correct? Explain.

12.




The spaceships are moving apart at 100,000 mph. Both ships were measured as equally long when on Earth, and both clocks were synchronized. A compares his own clock with B's clock. What does he (A) observe about B's clock?

______________________________________________

What does A observe about the length of B's ship?

______________________________________________

What does B observe about A's clock?

______________________________________________

What does B observe about the length of A's ship?

______________________________________________

13. Fill in the words which correctly describe how the two theories differ with respect to each of the physical dimensions.

| Dimensions | Classical Physics | The Special Theory of Relativity |
|---|---|---|
| the speed of light | | |
| time | | |
| distance (length) | | |

14. List the two basic assumptions on which the Theory of Relativity is based.

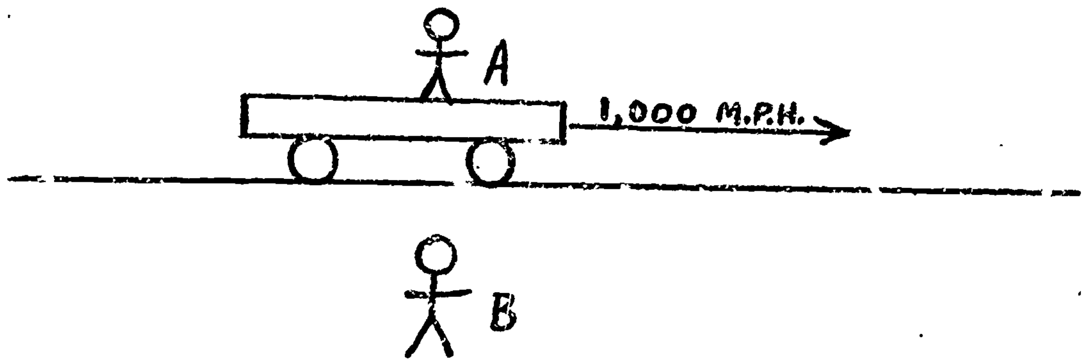
1. ______________________________________________

______________________________________________

2. ______________________________________________

______________________________________________

15.




The observer on the ground (B) finds the length of the car and comes up with a slightly shorter measurement from the man on the train. How would the man on the train (A) explain the fact that B's measurement was too short?

# APPENDIX B

Additional Results

Table 1-B

Summaries of Analyses of Variance of
IQ, Work Rate (on preliminary programs) and
Electrical Circuits Pretest Scores: Grade 5

(N = 264)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| IQ | Mode | 1 | .06 | - |
| | Setting | 1 | 3.06 | - |
| | IQ | 1 | 23370.77 | 408.22** |
| | M x S | 1 | 9.77 | - |
| | M x I | 1 | 16.00 | - |
| | S x I | 1 | .06 | - |
| | M x S x I | 1 | 4.50 | - |
| | Within Replicates | 248 | 57.25 | |
| WORK RATE (Atomics and Force Programs) | Mode | 1 | 102.52 | - |
| | Setting | 1 | 922.64 | 1.46 |
| | IQ | 1 | 17391.00 | 27.59** |
| | M x S | 1 | 87.89 | - |
| | M x I | 1 | 805.14 | 1.28 |
| | S x I | 1 | 1113.89 | 1.77 |
| | M x S x I | 1 | 708.74 | 1.12 |
| | Within Replicates | 248 | 630.40 | |
| PRETEST ELECTRICAL CIRCUITS | Mode | 1 | 45.56 | 1.05 |
| | Setting | 1 | 14.06 | - |
| | IQ | 1 | 1630.14 | 37.73** |
| | M x S | 1 | 8.27 | - |
| | M x I | 1 | 4.00 | - |
| | S x I | 1 | .25 | - |
| | M x S x I | 1 | 1.26 | - |
| | Within Replicates | 248 | 43.20 | |

** significant beyond the .01 level

Table 2-B

Summary Means and SD's of
Sixth Grade IQ Scores
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 108.26 | 11.89 | N.S. |
| | fixed-paced | 108.23 | 12.44 | |
| SETTING | isolated | 108.35 | 12.25 | N.S. |
| | group | 108.13 | 12.08 | |
| IQ | high | 117.80 | 7.78 | <.01 |
| | low | 98.69 | 7.17 | |

Table 3-B

Summary Means and SD's of Sixth Grade WORK RATES
(measured by time to complete Atomics and Force programs)
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 139.83 | 25.51 | N.S. |
| | fixed-paced | 141.09 | 27.31 | |
| SETTING | isolated | 138.56 | 26.17 | N.S. |
| | group | 142.36 | 26.56 | |
| IQ | high | 132.22 | 21.80 | <.01 |
| | low | 148.70 | 28.02 | |

Table 4-B

Summary Means and SD's of
Electrical Circuits PRETEST Scores: Grade 6
(N = 256)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 8.48 | 6.99 | N.S. |
| | fixed-paced | 7.63 | 6.97 | |
| SETTING | isolated | 7.82 | 7.16 | N.S. |
| | group | 8.29 | 6.81 | |
| IQ | high | 10.58 | 7.57 | <.01 |
| | low | 5.53 | 5.26 | |

Table 5-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Time to Complete Electrical Circuits Program
Predictor Variables: Total Pretest (on preliminary programs), Work Rate, and Electrical Circuits Pretest

(Based on Self-Paced, Isolated Ss: Grade 6)

Intercorrelations

| | | Time Electrical Circuits $X_1$ | Total Pretest $X_2$ | Work Rate $X_3$ | Electrical Circuits Pretest $X_4$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|
| Time Electrical Circuits | $X_1$ | | .033 | .675 | -.301 | 135.62 | 26.00 | 55 |
| Total Pretest | $X_2$ | | | -.111 | .524 | 12.31 | 10.38 | 55 |
| Work Rate | $X_3$ | | | | -.368 | 138.35 | 26.62 | 55 |
| Electrical Circuits Pretest | $X_4$ | | | | | 7.56 | 6.36 | 55 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| Total Pretest | $X_2$ | .191 | .033 | .006 |
| Work Rate | $X_3$ | .635 | .675 | .429 |
| Electrical Circuits Pretest | $X_4$ | -.168 | -.301 | .051 |

$R^2$ 1.234 = .485
R 1.234 = .697
$\sigma$ 1.234 = 19.368

Table 6-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Errors Electrical Circuits
Predictor Variables: IQ, Total Posttest (on preliminary programs), Work Rate, and Electrical Circuits Pretest

(Based on Self-Paced, Isolated Ss: Grade 6)

Intercorrelations

| | | Errors Electrical Circuits $X_1$ | IQ $X_2$ | Total Posttest $X_3$ | Work Rate $X_4$ | Electrical Circuits Pretest $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Errors Electrical Circuits | $X_1$ | | -.651 | -.735 | -.050 | -.335 | 120.89 | 73.20 | 55 |
| IQ | $X_2$ | | | .707 | -.361 | .369 | 108.38 | 11.52 | 55 |
| Total Posttest | $X_3$ | | | | -.162 | .431 | 114.66 | 50.80 | 55 |
| Work Rate | $X_4$ | | | | | -.368 | 138.35 | 26.52 | 55 |
| Electrical Circuits Pretest | $X_5$ | | | | | | 7.56 | 6.36 | 55 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.399 | -.651 | .260 |
| Total Posttest | $X_3$ | -.458 | -.735 | .337 |
| Work Rate | $X_4$ | -.306 | -.050 | .015 |
| Electrical Circuits Pretest | $X_5$ | -.103 | -.335 | .035 |

$R^2$ 1.2345 = .638
R 1.2345 = .799
$\sigma$ 1.2345 = 45.725

Table 7-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Electrical Circuits Posttest
Predictor Variables: IQ and Total Posttest (on preliminary programs)

(Based on Self-Paced, Isolated Ss: Grade 6)

Intercorrelations

| | | Electrical Circuits Posttest $X_1$ | IQ $X_2$ | Total Posttest $X_3$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|
| Electrical Circuits Posttest | $X_1$ | | .726 | .781 | 54.66 | 25.65 | 55 |
| IQ | $X_2$ | | | .707 | 108.38 | 11.52 | 55 |
| Total Posttest | $X_3$ | | | | 114.66 | 50.80 | 55 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | .347 | .726 | .251 |
| Total Posttest | $X_3$ | .536 | .781 | .419 |

$R^2$ 1.23 = .670
R 1.23 = .819
$\sigma$ 1.23 = 15.153

Table 8-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Electrical Circuits Retention
Predictor Variables: IQ, Corrected Reading Speed, Uncorrected Reading Speed, Total Pretest, Total Posttest, Total Errors, and Work Rate

(Based on Self-Paced, Isolated Ss: Grade 6)

Intercorrelations

| | | Electrical Circuits Retention $X_1$ | IQ $X_2$ | Corr. Read. Speed $X_3$ | Uncor. Read. Speed $X_4$ | Total Pretest $X_5$ | Total Posttest $X_6$ | Total Errors $X_7$ | Work Rate $X_8$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electrical Circuits Retention | $X_1$ | | .714 | .465 | .515 | .639 | .677 | -.483 | -.080 | 27.40 | 19.52 | 55 |
| IQ | $X_2$ | | | .708 | .748 | .492 | .707 | -.542 | -.361 | 108.38 | 11.52 | 55 |
| Corrected Reading Speed | $X_3$ | | | | .968 | .370 | .666 | -.482 | -.382 | 16.93 | 6.45 | 55 |
| Uncorrected Reading Speed | $X_4$ | | | | | .385 | .654 | -.481 | -.428 | 17.67 | 6.04 | 55 |
| Total Pretest | $X_5$ | | | | | | .513 | -.382 | -.111 | 12.31 | 10.38 | 55 |
| Total Posttest | $X_6$ | | | | | | | -.738 | -.162 | 114.66 | 50.80 | 55 |
| Total Errors | $X_7$ | | | | | | | | -.014 | 66.09 | 48.83 | 55 |
| Work Rate | $X_8$ | | | | | | | | | 138.35 | 26.62 | 55 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | .467 | .714 | .333 |
| Corrected Reading Speed | $X_3$ | -.646 | .465 | -.300 |
| Uncorrected Reading Speed | $X_4$ | .569 | .515 | .293 |
| Total Pretest | $X_5$ | .308 | .639 | .197 |
| Total Posttest | $X_6$ | .368 | .677 | .249 |
| Total Errors | $X_7$ | .125 | -.483 | -.060 |
| Work Rate | $X_8$ | .181 | -.080 | -.014 |

$R^2$ 1.2345678 = .698
R 1.2345678 = .835
$\sigma$ 1.2345678 = 11.606

Table 9-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Time to Complete Electrical Circuits Program
Predictor Variables: Corrected Reading Speed, Uncorrected Reading Speed, Work Rate, and Electrical Circuits Pretest

(Based on Self-Paced, Grouped Ss: Grade 6)

Intercorrelations

| | | Time Electrical Circuits $X_1$ | Corrected Reading Speed $X_2$ | Uncorrected Reading Speed $X_3$ | Work Rate $X_4$ | Electrical Circuits Pretest $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Time Electrical Circuits | $X_1$ | | -.263 | -.282 | .588 | .012 | 144.16 | 20.59 | 75 |
| Corrected Reading Speed | $X_2$ | | | .964 | -.393 | .465 | 18.30 | 6.24 | 74 |
| Uncorrected Reading Speed | $X_3$ | | | | -.346 | .434 | 18.72 | 5.97 | 74 |
| Work Rate | $X_4$ | | | | | -.181 | 141.14 | 25.03 | 64 |
| Electrical Circuits Pretest | $X_5$ | | | | | | 9.07 | 7.14 | 74 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| Corrected Reading Speed | $X_2$ | .521 | -.263 | -.137 |
| Uncorrected Reading Speed | $X_3$ | -.645 | -.282 | .182 |
| Work Rate | $X_4$ | .598 | .588 | .352 |
| Electrical Circuits Pretest | $X_5$ | .158 | .012 | .002 |

$R^2$ 1.2345 = .399
R 1.2345 = .632
$\sigma$ 1.2345 = 16.623

Table 10-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Errors Electrical Circuits
Predictor Variables: IQ, Total Errors, Work Rate, and Electrical Circuits Pretest

(Based on Self-Paced, Grouped Ss: Grade 6)

Intercorrelations

| | | Errors Electrical Circuits $X_1$ | IQ $X_2$ | Total Errors $X_3$ | Work Rate $X_4$ | Electrical Circuits Pretest $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Errors Electrical Circuits | $X_1$ | | -.567 | .717 | .104 | -.428 | 100.31 | 66.96 | 75 |
| IQ | $X_2$ | | | -.378 | -.267 | .420 | 108.73 | 11.69 | 75 |
| Total Errors | $X_3$ | | | | -.173 | -.307 | 53.78 | 37.73 | 67 |
| Work Rate | $X_4$ | | | | | -.181 | 141.14 | 25.03 | 64 |
| Electrical Circuits Pretest | $X_5$ | | | | | | 9.07 | 7.14 | 74 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.259 | -.567 | .147 |
| Total Errors | $X_3$ | .605 | .717 | .434 |
| Work Rate | $X_4$ | .119 | .104 | .012 |
| Electrical Circuits Pretest | $X_5$ | -.111 | -.428 | .048 |

$R^2$ 1.2345 = .641
R 1.2345 = .801
$\sigma$ 1.2345 = 41.795

Table 11-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Electrical Circuits Posttest
Predictor Variables: Corrected Reading Speed, Total Posttest, Total Errors, and Work Rate

(Based on Self-Paced, Grouped Ss: Grade 6)

Intercorrelations

| | | Electrical Circuits Posttest $X_1$ | Corrected Reading Speed $X_2$ | Total Posttest $X_3$ | Total Errors $X_4$ | Total Time $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Electrical Circuits Posttest | $X_1$ | | .655 | .818 | -.397 | -.333 | 55.19 | 28.27 | 75 |
| Corrected Reading Speed | $X_2$ | | | .634 | -.319 | -.393 | 18.30 | 6.24 | 74 |
| Total Posttest | $X_3$ | | | | -.406 | -.217 | 118.01 | 48.81 | 68 |
| Total Errors | $X_4$ | | | | | -.173 | 53.78 | 37.73 | 67 |
| Total Time | $X_5$ | | | | | | 141.14 | 25.03 | 64 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| Corrected Reading Speed | $X_2$ | .150 | .655 | .098 |
| Total Posttest | $X_3$ | .643 | .818 | .526 |
| Total Errors | $X_4$ | -.116 | -.397 | .046 |
| Total Time | $X_5$ | -.155 | -.333 | .052 |

$R^2$ 1.2345 = .722
R 1.2345 = .850
$\sigma$ 1.2345 = 15.527

Table 12-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Electrical Circuits Retention
Predictor Variables: Total Pretest, Total Posttest, Total Errors Electrical Circuits Pretest

(Based on Self-Paced, Grouped Ss: Grade 6)

Intercorrelations

| | | Electrical Circuits Retention $X_1$ | Total Pretest $X_2$ | Total Posttest $X_3$ | Total Errors $X_4$ | Electrical Circuits Pretest $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Electrical Circuits Retention | $X_1$ | | .567 | .723 | -.440 | .595 | 31.96 | 21.67 | 75 |
| Total Pretest | $X_2$ | | | .424 | -.290 | .640 | 15.07 | 13.08 | 74 |
| Total Posttest | $X_3$ | | | | -.406 | .557 | 118.02 | 48.81 | 68 |
| Total Errors | $X_4$ | | | | | -.307 | 53.78 | 37.73 | 67 |
| Electrical Circuits Pretest | $X_5$ | | | | | | 9.07 | 7.14 | |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| Total Pretest | $X_2$ | .237 | .567 | .134 |
| Total Posttest | $X_3$ | .501 | .723 | .362 |
| Total Errors | $X_4$ | -.130 | -.440 | .057 |
| Electrical Circuits Pretest | $X_5$ | .125 | .595 | .074 |

$R^2$ 1.2345 = .628
R 1.2345 = .792
$\sigma$ 1.2345 = 13.771

Table 13-B

Summaries of Analysis of Variance of IQ, Work Rate (on preliminary programs) and Relativity Pretest Scores: Grade 12

(N = 176)

| | Source | D.F. | Mean Squares | F |
|---|---|---|---|---|
| IQ | Mode | 1 | .77 | - |
| | Setting | 1 | .22 | - |
| | IQ | 1 | 18063.07 | 513.14** |
| | M x S | 1 | 4.06 | - |
| | M x I | 1 | 2.94 | - |
| | S x I | 1 | .24 | - |
| | M x S x I | 1 | 17.21 | - |
| | Within Replicates | 168 | 35.20 | |
| WORK RATE (Particles I and II Programs) | Mode | 1 | 83.19 | - |
| | Setting | 1 | 33.71 | - |
| | IQ | 1 | 9765.47 | 57.63** |
| | M x S | 1 | 535.50 | 3.16 |
| | M x I | 1 | .06 | - |
| | S x I | 1 | 15.94 | - |
| | M x S x I | 1 | 692.06 | 4.08* |
| | Within Replicates | 168 | 169.46 | |
| PRETEST RELATIVITY | Mode | 1 | 250.57 | 3.66 |
| | Setting | 1 | .36 | - |
| | IQ | 1 | 927.36 | 13.54** |
| | M x S | 1 | 61.46 | - |
| | M x I | 1 | 71.27 | 1.04 |
| | S x I | 1 | 24.75 | - |
| | M x S x I | 1 | 127.84 | 1.87 |
| | Within Replicates | 168 | 63.49 | |

* significant beyond the .05 level

** significant beyond the .01 level

Table 14-B

Summary Means and SD's of
Twelfth Grade IQ Scores
(N = 176)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 112.23 | 11.56 | N.S. |
| | fixed-paced | 112.10 | 11.93 | |
| SETTING | isolated | 112.14 | 11.55 | N.S. |
| | group | 112.19 | 11.94 | |
| IQ | high | 122.30 | 5.08 | <.01 |
| | low | 102.03 | 6.51 | |

Table 15-B

Summary Means and SD's of Twelfth Grade WORK RATES
(measured by time to complete Particles I and II Programs)
( N = 176)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 94.39 | 15.63 | N.S. |
| | fixed-paced | 93.01 | 14.49 | |
| SETTING | isolated | 93.26 | 13.45 | N.S. |
| | group | 94.14 | 16.55 | |
| IQ | high | 86.25 | 12.13 | <.01 |
| | low | 101.15 | 13.99 | |

Table 16-B

Summary Means and SD's of
Relativity PRETEST Scores: Grade 12
(N = 176)

| | Levels of Independent Variables | Mean | S.D. | Sign. Level |
|---|---|---|---|---|
| MODE | self-paced | 9.50 | 7.31 | N.S. |
| | fixed-paced | 11.89 | 9.63 | |
| SETTING | isolated | 10.74 | 7.69 | N.S. |
| | group | 10.65 | 9.49 | |
| IQ | high | 12.99 | 9.86 | <.01 |
| | low | 8.40 | 6.42 | |

Table 17-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Time to Complete Relativity Program
Predictor Variables: IQ, Corrected Reading Speed, Uncorrected Reading Speed, Total Posttest Score (on preliminary programs), and Work Rate

(Based on Self-Paced, Isolated Ss: Grade 12)

Intercorrelations

| | | Time Relativity $X_1$ | IQ $X_2$ | Corrected Reading Speed $X_3$ | Uncorrected Reading Speed $X_4$ | Total Posttest $X_5$ | Work Rate $X_6$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Time Relativity | $X_1$ | | -.438 | -.625 | -.635 | -.436 | .633 | 86.31 | 18.83 | 52 |
| IQ | $X_2$ | | | .426 | .396 | .654 | -.571 | 111.17 | 11.43 | 52 |
| Corrected Reading Speed | $X_3$ | | | | .99? | .318 | -.702 | 39.44 | 10.49 | 52 |
| Uncorrected Reading Speed | $X_4$ | | | | | .303 | -.693 | 39.71 | 10.57 | 52 |
| Total Posttest | $X_5$ | | | | | | -.442 | 177.33 | 23.63 | 52 |
| Work Rate | $X_6$ | | | | | | | 91.23 | 14.60 | 52 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.236 | -.483 | .114 |
| Corrected Reading Speed | $X_3$ | 3.713 | -.625 | -2.321 |
| Uncorrected Reading Speed | $X_4$ | -4.029 | -.635 | 2.558 |
| Total Posttest | $X_5$ | -.131 | -.436 | .057 |
| Work Rate | $X_6$ | .254 | .633 | .161 |

$R^2$ 1.23456 = .570
R 1.23456 = .755
$\sigma$ 1.23456 = 13.122

Table 18-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Errors Relativity Program
Predictor Variables: IQ, Total Posttest, Total Errors (on preliminary programs), and Work Rate

(Based on Self-Paced, Isolated Ss: Grade 12)

Intercorrelations

| | | Errors Relativity $X_1$ | IQ $X_2$ | Total Posttest $X_3$ | Total Errors $X_4$ | Work Rate $X_5$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|
| Errors Relativity | $X_1$ | | -.668 | -.632 | .559 | .505 | 60.62 | 32.47 | 52 |
| [illegible] | $X_2$ | | | .654 | -.518 | -.571 | 111.17 | 11.43 | 52 |
| Total Posttest | $X_3$ | | | | -.712 | -.442 | 177.33 | 23.63 | 52 |
| Total Errors | $X_4$ | | | | | .405 | 17.81 | 19.36 | 52 |
| Work Rate | $X_5$ | | | | | | 91.23 | 14.60 | 52 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.364 | -.668 | .243 |
| Total Posttest | $X_3$ | -.223 | -.632 | .141 |
| Total Errors | $X_4$ | .157 | .559 | .088 |
| Work Rate | $X_5$ | .135 | .505 | .068 |

$R^2$ 1.2345 = .540
R 1.2345 = .735
$\sigma$ 1.2345 = 23.168

Table 19-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Relativity Posttest
Predictor Variables: IQ, Total Pretest, Total Posttest, Total Errors, and Work Rate

(Based on Self-Paced, Isolated Ss: Grade 12)

Intercorrelations

| | | Posttest Relativity $X_1$ | IQ $X_2$ | Total Pretest $X_3$ | Total Posttest $X_4$ | Total Errors $X_5$ | Work Rate $X_6$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Posttest Relativity | $X_1$ | | .730 | .417 | .676 | -.386 | -.537 | 76.77 | 18.98 | 52 |
| IQ | $X_2$ | | | .581 | .654 | -.518 | -.571 | 111.17 | 11.43 | 52 |
| Total Pretest | $X_3$ | | | | .595 | -.519 | -.489 | 39.19 | 16.25 | 52 |
| Total Posttest | $X_4$ | | | | | -.712 | -.442 | 177.33 | 23.63 | 52 |
| Total Errors | $X_5$ | | | | | | .405 | 17.81 | 19.36 | 52 |
| Work Rate | $X_6$ | | | | | | | 91.23 | 14.60 | 52 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k} r_{1k}$ | |
|---|---|---|---|---|---|
| IQ | $X_2$ | .478 | .730 | .349 | |
| Total Pretest | $X_3$ | -.15[illegible] | .417 | -.063 | $R^2$ 1.23456 = .664 |
| Total Posttest | $X_4$ | .546 | .676 | .369 | R 1.23456 = .815 |
| Total Errors | $X_5$ | .252 | -.386 | -.097 | $\sigma$ 1.23456 = 11.698 |
| Work Rate | $X_6$ | -.199 | -.537 | .107 | |

Table 20-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Relativity Retention
Predictor Variables: IQ, Total Posttest, Total Errors

(Based on Self-Paced, Isolated Ss: Grade 12)

Intercorrelations

| | | Retention Relativity $X_1$ | IQ $X_2$ | Total Posttest $X_3$ | Total Errors $X_4$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|
| Retention Relativity | $X_1$ | | .708 | .585 | -.377 | 61.65 | 21.81 | 52 |
| IQ | $X_2$ | | | .654 | -.518 | 111.17 | 11.43 | 52 |
| Total Posttest | $X_3$ | | | | -.712 | 177.33 | 23.63 | 52 |
| Total Errors | $X_4$ | | | | | 17.81 | 19.36 | 52 |

Regression Analysis

| | | 1k | $r_{1k}$ | 1k $r_{1k}$ | |
|---|---|---|---|---|---|
| IQ | $X_2$ | .582 | .708 | .412 | $R^2$ 1.234 = .537 |
| Total Posttest | $X_3$ | .304 | .585 | .178 | R 1.234 = .734 |
| | | | | | $\sigma$ 1.234 = 15.452 |
| Total Errors | $X_4$ | .141 | -.377 | -.053 | |



ERIC

Table 21-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Time to Complete Relativity Program
Predictor Variables: IQ, Corrected Reading Speed, Uncorrected Reading Speed, Total Posttest, Total Errors, and Work Rate
(Based on Self-Paced, Grouped Ss: Grade 12)

Intercorrelations

| | | Time Relativity $X_1$ | IQ $X_2$ | Corrected Reading Speed $X_3$ | Uncorrected Reading Speed $X_4$ | Total Posttest $X_5$ | Total Errors $X_6$ | Work Rate $X_7$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Relativity | $X_1$ | | -.553 | -.362 | -.353 | -.275 | .467 | .805 | 94.33 | 16.24 | 51 |
| IQ | $X_2$ | | | .520 | .520 | .664 | -.687 | -.534 | 112.41 | 10.72 | 51 |
| Corrected Reading Speed | $X_3$ | | | | .999 | .335 | -.427 | -.428 | 37.20 | 9.42 | 50 |
| Uncorrected Reading Speed | $X_4$ | | | | | .335 | -.423 | -.427 | 37.38 | 9.30 | 50 |
| Total Posttest | $X_5$ | | | | | | -.737 | -.340 | 176.32 | 25.01 | 47 |
| Total Errors | $X_6$ | | | | | | | .402 | 19.55 | 22.21 | 47 |
| Work Rate | $X_7$ | | | | | | | | 95.86 | 15.32 | 51 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.227 | -.553 | .126 |
| Corrected Reading Speed | $X_3$ | -2.577 | -.362 | .933 |
| Uncorrected Reading Speed | $X_4$ | 2.653 | -.353 | -.937 |
| Total Posttest | $X_5$ | .275 | -.275 | -.076 |
| Total Errors | $X_6$ | .251 | .467 | .117 |
| Work Rate | $X_7$ | .705 | .805 | .568 |

$R^2$ 1.234567 = .729
$R$ 1.234567 = .854
$\sigma$ 1.234567 = 9.058

Table 22-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Errors Relativity
Predictor Variables: IQ, Corrected Reading Speed, Uncorrected Reading Speed, Total Posttest, Total Errors, and Work Rate
(Based on Self-Paced, Grouped Ss: Grade 12)

Intercorrelations

| | | Errors Relativity $X_1$ | IQ $X_2$ | Corrected Reading Speed $X_3$ | Uncorrected Reading Speed $X_4$ | Total Posttest $X_5$ | Total Errors $X_6$ | Work Rate $X_7$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Errors Relativity | $X_1$ | | -.703 | -.469 | -.475 | -.788 | .779 | .255 | 45.51 | 34.06 | 51 |
| IQ | $X_2$ | | | .520 | .520 | .664 | -.687 | -.534 | 112.41 | 10.72 | 51 |
| Corrected Reading Speed | $X_3$ | | | | .999 | .335 | -.427 | -.428 | 37.20 | 9.42 | 50 |
| Uncorrected Reading Speed | $X_4$ | | | | | .335 | -.423 | -.427 | 37.38 | 9.30 | 50 |
| Total Posttest | $X_5$ | | | | | | -.737 | -.340 | 176.32 | 25.01 | 47 |
| Total Errors | $X_6$ | | | | | | | .402 | 19.55 | 22.21 | 47 |
| Work Rate | $X_7$ | | | | | | | | 95.86 | 15.32 | 51 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | -.214 | -.703 | .150 |
| Corrected Reading Speed | $X_3$ | 2.970 | -.469 | -1.393 |
| Uncorrected Reading Speed | $X_4$ | -3.131 | -.475 | 1.487 |
| Total Posttest | $X_5$ | -.387 | -.788 | .305 |
| Total Errors | $X_6$ | .374 | .779 | .291 |
| Work Rate | $X_7$ | -.206 | .255 | -.053 |

$R^2$ 1.234567 = .789
$R$ 1.234567 = .888
$\sigma$ 1.234567 = 16.763

Table 23-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Relativity Posttest
Predictor Variables: Corrected Reading Speed, Uncorrected Reading Speed, Total Posttest, Total Errors, and Relativity Pretest

(Based on Self-Paced, Grouped Ss: Grade 12)

Intercorrelations

| | | Posttest Relativity $X_1$ | Corrected Reading Speed $X_2$ | Uncorrected Reading Speed $X_3$ | Total Posttest $X_4$ | Total Errors $X_5$ | Pretest Relativity $X_6$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|
| Posttest Relativity | $X_1$ | | .479 | .483 | .802 | -.808 | .111 | 77.14 | 19.05 | 51 |
| Corrected Reading Speed | $X_2$ | | | .999 | .335 | -.427 | -.185 | 37.20 | 9.42 | 50 |
| Uncorrected Reading Speed | $X_3$ | | | | .335 | -.423 | -.187 | 37.38 | 9.30 | 50 |
| Total Posttest | $X_4$ | | | | | -.737 | .005 | 176.32 | 25.01 | 47 |
| Total Errors | $X_5$ | | | | | | -.103 | 19.55 | 22.21 | 47 |
| Pretest Relativity | $X_6$ | | | | | | | 9.74 | 7.26 | 50 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| Corrected Reading Speed | $X_2$ | -2.387 | .479 | -1.143 |
| Uncorrected Reading Speed | $X_3$ | 2.568 | .483 | 1.240 |
| Total Posttest | $X_4$ | .443 | .802 | .355 |
| Total Errors | $X_5$ | -.405 | -.808 | .327 |
| Pretest Relativity | $X_6$ | .107 | .111 | .012 |

$R^2$ 1.23456 = .791
$R$ 1.23456 = .890
$\sigma$ 1.23456 = 9.230

Table 24-B

MULTIPLE REGRESSION ANALYSIS

Criterion Variable: Relativity Retention
Predictor Variables: IQ, Total Errors, and Work Rate

(Based on Self-Paced, Grouped Ss: Grade 12)

Intercorrelations

| | | Retention Relativity $X_1$ | IQ $X_2$ | Total Errors $X_3$ | Work Rate $X_4$ | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|
| Retention Relativity | $X_1$ | | .529 | -.554 | -.115 | 60.78 | 20.64 | 51 |
| IQ | $X_2$ | | | -.685 | -.534 | 112.41 | 10.72 | 51 |
| Total Errors | $X_3$ | | | | .384 | 18.02 | 21.96 | 51 |
| Work Rate | $X_4$ | | | | | 95.86 | 15.32 | 51 |

Regression Analysis

| | | $\beta_{1k}$ | $r_{1k}$ | $\beta_{1k}r_{1k}$ |
|---|---|---|---|---|
| IQ | $X_2$ | .405 | .529 | .214 |
| Total Errors | $X_3$ | -.370 | -.554 | .205 |
| Work Rate | $X_4$ | .243 | -.115 | -.028 |

$R^2$ 1.234 = .392
$R$ 1.234 = .626
$\sigma$ 1.234 = 16.768

CODE FOR IDENTIFYING VARIABLES
IN CORRELATIONAL MATRICES APPEARING
IN TABLES 25-B AND 26-B

1. IQ
2. Corrected Reading Speed
3. Uncorrected Reading Speed
4. Pretest Score on first preliminary program
5. Pretest Score on second preliminary program
6. Sum of (4) and (5): Total Pretest
7. Posttest Score on first preliminary program
8. Posttest Score on second preliminary program
9. Sum of (7) and (8): Total Posttest
10. Number of Errors committed on first preliminary program
11. Number of Errors committed on second preliminary program
12. Sum of (10) and (11): Total Errors
13. Time to complete first preliminary program
14. Time to complete second preliminary program
15. Sum of (13) and (14): Work Rate
16. Pretest Score on experimental program
17. Posttest Score on experimental program
18. Number of Errors committed on experimental program
19. Time to complete experimental program
20. Retention Test Score on experimental program

Table 25-B

Correlational Matrix Based on All
Non-Missing Cases: Grade 6

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | .68 | .51 | .42 | .38 | .49 | .72 | .66 | .72 | -.45 | -.39 | -.44 | -.34 | -.36 | -.38 | .50 | .70 | -.63 | -.14 | .64 | 107.24 | 12.81 | 304 |
| 2 | 284 | | .82 | .31 | .33 | .39 | .59 | .54 | .60 | -.37 | -.34 | -.39 | -.34 | -.40 | -.38 | .43 | .64 | -.53 | -.21 | .51 | 17.51 | 7.43 | 288 |
| 3 | 284 | 288 | | .26 | .26 | .32 | .44 | .41 | .46 | -.24 | -.17 | -.25 | -.34 | -.44 | -.40 | .34 | .51 | -.38 | -.22 | .47 | 18.50 | 7.35 | 288 |
| 4 | 286 | 287 | 287 | | .35 | .81 | .41 | .41 | .44 | -.26 | -.23 | -.27 | -.20 | -.20 | -.22 | .49 | .42 | -.36 | -.04 | .52 | 3.94 | 6.22 | 290 |
| 5 | 287 | 288 | 288 | 290 | | .83 | .32 | .35 | .36 | -.22 | -.19 | -.23 | -.20 | -.29 | -.26 | .47 | .36 | -.36 | -.10 | .41 | 8.38 | 6.43 | 291 |
| 6 | 286 | 287 | 287 | 290 | 290 | | .44 | .46 | .48 | -.29 | -.26 | -.30 | -.24 | -.30 | -.29 | .59 | .47 | -.44 | -.08 | .56 | 12.31 | 10.39 | 290 |
| 7 | 295 | 282 | 282 | 283 | 284 | 283 | | .83 | .95 | -.54 | -.52 | -.56 | -.24 | -.22 | -.25 | .53 | .82 | -.70 | -.04 | .74 | 51.10 | 26.87 | 299 |
| 8 | 287 | 275 | 275 | 277 | 278 | 277 | 283 | | .94 | -.51 | -.53 | -.55 | -.25 | -.25 | -.27 | .50 | .77 | -.63 | -.13 | .63 | 54.90 | 26.52 | 291 |
| 9 | 279 | 269 | 269 | 270 | 271 | 270 | 285 | 283 | | -.54 | -.55 | -.58 | -.26 | -.26 | -.28 | .5[illegible] | .83 | -.70 | -.07 | .72 | 105.67 | 51.08 | 283 |
| 10 | 294 | 281 | 281 | 282 | 283 | 282 | 297 | 281 | 281 | | -.75 | .92 | -.12 | -.04 | -.10 | .29 | -.46 | .56 | -.14 | -.43 | 28.66 | 26.10 | 297 |
| 11 | 285 | 273 | 273 | 275 | 276 | 275 | 280 | 288 | 280 | 280 | | .90 | .00 | .04 | .06 | .26 | -.43 | .53 | -.08 | -.38 | 32.24 | 24.12 | 288 |
| 12 | 277 | 267 | 267 | 268 | 269 | 268 | 280 | 280 | 280 | 280 | 280 | | -.06 | .04 | .02 | .30 | -.47 | .58 | -.07 | -.42 | 60.95 | 46.11 | 280 |
| 13 | 302 | 287 | 287 | 289 | 290 | 289 | 298 | 289 | 282 | 297 | 287 | 280 | | .78 | .93 | .26 | -.26 | .17 | .60 | -.23 | 58.16 | 13.20 | 305 |
| 14 | 299 | 284 | 284 | 286 | 287 | 286 | 294 | 290 | 282 | 293 | 288 | 280 | 301 | | .95 | .23 | -.26 | .18 | .61 | -.21 | 82.59 | 15.14 | 302 |
| 15 | 259 | 245 | 245 | 247 | 248 | 247 | 252 | 247 | 240 | 252 | 246 | 239 | 259 | 259 | | .27 | -.30 | .18 | .63 | -.25 | 140.27 | 26.25 | 259 |
| 16 | 287 | 288 | 288 | 290 | 291 | 290 | 284 | 278 | 271 | 283 | 276 | 269 | 290 | 287 | 248 | | .51 | -.47 | -.10 | .57 | 7.87 | 7.06 | 291 |
| 17 | 285 | 271 | 271 | 273 | 274 | 273 | 281 | 275 | 268 | 280 | 273 | 266 | 288 | 287 | 259 | 274 | | -.73 | -.03 | .79 | 51.56 | 26.96 | 288 |
| 18 | 284 | 271 | 271 | 273 | 274 | 273 | 280 | 274 | 267 | 280 | 273 | 266 | 287 | 286 | 259 | 274 | 287 | | -.20 | -.65 | 130.70 | 74.51 | 287 |
| 19 | 139 | 135 | 135 | 137 | 137 | 137 | 139 | 132 | 131 | 139 | 131 | 130 | 140 | 139 | 128 | 137 | 140 | 140 | | .04 | 140.30 | 23.03 | 140 |
| 20 | 276 | 254 | 264 | 266 | 267 | 266 | 272 | 265 | 258 | 271 | 263 | 256 | 279 | 277 | 250 | 267 | 278 | 277 | 138 | | 27.18 | 20.43 | 279 |

## Table 26-B

**Correlational Matrix Based on All Non-Missing Cases: Grade 12**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Mean | S.D. | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | .57 | .57 | .51 | .56 | .62 | .72 | .62 | .74 | -.61 | -.54 | -.61 | -.55 | -.59 | -.62 | .36 | .69 | -.54 | -.61 | .61 | 109.50 | 12.59 | 289 |
| 2 | 286 | | .99 | .24 | .29 | .32 | .48 | .41 | .48 | -.46 | -.37 | -.43 | -.56 | -.49 | -.56 | .23 | .42 | -.39 | -.47 | .34 | 36.99 | 10.01 | 294 |
| 3 | 286 | 294 | | .24 | .29 | .32 | .47 | .40 | .48 | -.46 | -.37 | -.43 | -.56 | -.49 | -.56 | .23 | .42 | -.39 | -.47 | .34 | 37.24 | 9.88 | 294 |
| 4 | 285 | 293 | 293 | | .49 | .79 | .46 | .35 | .45 | -.39 | -.35 | -.40 | -.38 | -.34 | -.38 | .36 | .39 | -.36 | -.34 | .43 | 12.68 | 8.24 | 293 |
| 5 | 284 | 292 | 292 | 292 | | .91 | .53 | .48 | .56 | -.41 | -.41 | -.44 | -.36 | -.37 | -.39 | .34 | .41 | -.34 | -.34 | .43 | 22.08 | 12.62 | 292 |
| 6 | 284 | 292 | 292 | 292 | 292 | | .57 | .49 | .58 | -.47 | -.44 | -.49 | -.42 | -.42 | -.45 | .38 | .46 | -.40 | -.41 | .50 | 34.65 | 18.22 | 292 |
| 7 | 273 | 278 | 278 | 278 | 277 | 277 | | .72 | .95 | -.72 | -.61 | -.70 | -.47 | -.52 | -.53 | .34 | .64 | -.56 | -.42 | .56 | 80.86 | 20.95 | 281 |
| 8 | 266 | 272 | 272 | 272 | 271 | 271 | 269 | | .90 | -.54 | -.58 | -.58 | -.39 | -.45 | -.45 | .24 | .59 | -.51 | -.36 | .44 | 88.86 | 15.51 | 274 |
| 9 | 261 | 267 | 267 | 267 | 266 | 266 | 269 | 269 | | -.69 | -.64 | -.70 | -.48 | -.54 | -.56 | .33 | .70 | -.61 | -.46 | .58 | 169.44 | 34.08 | 269 |
| 10 | 273 | 278 | 278 | 278 | 277 | 277 | 281 | 269 | 269 | | .69 | .90 | .34 | .40 | .40 | -.23 | -.51 | .51 | .43 | -.44 | 11.68 | 13.89 | 281 |
| 11 | 266 | 272 | 272 | 272 | 271 | 271 | 269 | 274 | 269 | 269 | | .88 | .34 | .29 | .34 | -.24 | -.49 | .43 | .36 | -.32 | 8.40 | 11.93 | 274 |
| 12 | 261 | 267 | 267 | 267 | 266 | 266 | 269 | 269 | 269 | 269 | 269 | | .36 | .38 | .40 | -.24 | -.56 | .52 | .45 | -.42 | 20.65 | 24.66 | 269 |
| 13 | 278 | 283 | 283 | 283 | 282 | 282 | 281 | 274 | 269 | 281 | 274 | 269 | | .72 | .93 | -.34 | -.44 | .41 | .60 | -.39 | 55.48 | 10.45 | 286 |
| 14 | 278 | 283 | 283 | 283 | 282 | 282 | 281 | 274 | 269 | 281 | 274 | 269 | 286 | | .92 | -.28 | -.44 | .36 | .56 | -.33 | 42.26 | 9.92 | 286 |
| 15 | 289 | 293 | 293 | 292 | 291 | 291 | 281 | 274 | 269 | 281 | 274 | 269 | 286 | 286 | | -.33 | -.48 | .42 | .64 | -.39 | 97.57 | 18.62 | 297 |
| 16 | 286 | 294 | 294 | 293 | 292 | 292 | 278 | 272 | 267 | 278 | 272 | 267 | 283 | 283 | 293 | | .24 | -.19 | -.27 | .27 | 10.08 | 8.41 | 294 |
| 17 | 217 | 218 | 218 | 217 | 217 | 217 | 211 | 210 | 207 | 211 | 210 | 207 | 214 | 214 | 219 | 218 | | -.75 | -.38 | .72 | 73.63 | 19.35 | 219 |
| 18 | 217 | 218 | 218 | 217 | 217 | 217 | 211 | 210 | 207 | 211 | 210 | 207 | 214 | 214 | 219 | 218 | 219 | | .13 | -.67 | 66.61 | 37.44 | 219 |
| 19 | 217 | 218 | 218 | 217 | 217 | 217 | 211 | 210 | 207 | 211 | 210 | 207 | 214 | 214 | 219 | 218 | 219 | 219 | | -.31 | 87.40 | 21.99 | 164 |
| 20 | 217 | 218 | 218 | 217 | 217 | 217 | 211 | 210 | 207 | 211 | 210 | 207 | 214 | 214 | 219 | 218 | 219 | 219 | 219 | | 56.15 | 21.85 | 219 |